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EXTRATERRESTRIAL RESEARCH IN THE FEDERAL REPUBLIC
OF GERMANY

German Research Society for Air and Space Travel

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16. Abstract This German program for basic extraterrestrial research is an essential, successful and world-wide recognized part of the space program and has the same attributes for basic research in the Federal Republic of Germany. It covers all major scientific disciplines.			
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EXTRATERRESTRIAL RESEARCH

in the

FEDERAL REPUBLIC OF GERMANY

A survey prepared

by the

DEUTSCHE FORSCHUNGS- UND VERSUCHANSTALT FUER LUFT-

UND RAUMFAHRT E.V.

BEREICH RAUMFAHRT

HAUPTABTEILUNG TECHNOLOGIE UND NUTZUNGSPROGRAMME

ABTEILUNG EXTRATERRESTRIK (RF-TN2)

(GERMAN RESEARCH SOCIETY FOR AIR AND SPACE TRAVEL)

DFVLR

RF-TN

5.5.1986

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5.5.1986

EXTRATERRESTRIAL RESEARCH IN THE FEDERAL REPUBLIC OF GERMANY

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At the time of the European comet probe GIOTTO rendezvous with the comet Halley, on March 13, 1986 at the Operations Center for Space Exploration (ESOC) in Darmstadt; the Federal Minister of Research and Technology (BMFT) declared:

"Exploration of our solar system and deep space beyond is one of science's greatest challenges of our time. Our ideas of the structure of the universe have undergone basic changes in the last two decades. This revolution of our knowledge continues; their scientific and philosophical effects have not yet been fully grasped. Thanks to technological advances of late we have discovered unsuspected phenomena which throw a completely new light on the question of creation and evolution of galaxies, stars, the solar system, our planets, in fact, the whole cosmos. Space exploration, penetrating ever further into space and time, makes a fundamental contribution to the expansion of our knowledge."

The program of basic extraterrestrial research is receiving generous financial support from the Federal Government.

An agreement with the DFG (German Research Society) in 1964 transferred complete responsibility to the BMFT (formerly BMWF) with respect to the use of high altitude research rockets, satellites and space probes. The relatively high costs for such types of research, the international cooperation required for the execution of such projects as well as the general advancement of technology involved with such programs, would have otherwise exceeded the framework of the German Research Society (DFG).

Extraterrestrial research is multi-disciplinary and its method is defined by the use of space flight technology. It supplements the classical methods (e.g. telescopes on earth) and directs the general and international progress for all special research sectors involved in it.

The program is of perpetual interest to the BMFT and includes the following areas:

- Astronomy, astrophysics
- Solar-terrestrial relationships subdivided into
 - Aeronomy (exploration of the high aerospace)
 - Magneto-sphere physics and plasma physics
 - Interplanetary space, planet exploration.

Participants:

At present about 25 scientific institutes of the Max-Planck Society (MPG), universities as well as the DFVLR and numerous small and large companies are participating in the program.

Program structure and organization is shown in Fig. 1. The Federal Republic is participating in

3

- purely national projects
- bi-and multilateral projects (mainly with the USA space agency NASA)
- European projects within the science program of the European Space Agency (ESA).

All this produces a well-balanced mixture of short-term and long-term programs.

Short-term programs are of importance to universities since it facilitates the education of young space scientists even when allowing for large fluctuations of staff at universities.

Events since inception:

The program was started in 1962 with high-altitude rockets (HFR) in preparation for the first satellite missions: magneto-sphere satellite AZUR (launch 1969) and aeronomy satellites AEROS A and B (launch 1972 and 1974). NASA was approached in 1964 for cooperation purposes.

The main focus of the first phase was on the solar-terrestrial relationship. This phase was carried out in cooperation with NASA (AZUR, AEROS) and with the participation of the European satellites ESRO IV and HEOS as part of the ESA (formerly ESRO) program.

The first large-scale project was the solar probes HELIOS A and B (launch 1974 and 1976). This first project with somewhat of a pioneer character was carried out in conjunction with NASA. It served to explore the interplanetary space crossing the orbit of Mercury and posed extreme requirements on science and technology.

Fig. 1: Organization of the German Space Exploration Program 4

- 1) Others
- 2) Ad hoc committees
- 3) Other member states
- 4) European
- 5) Earth observation, telecommunication, microgravitation, etc.
- 6) Extraterrestrial research
- 7) Expert committees
- 8) Project management, system technology, operations
- 9) Contracts
- 10) Financial support
- 11) Industry
- 12) Universities, Max Planck Institutes, etc.
- 13) System technology, pay-loads, satellites
- 14) Science, instrumentation, evaluation.

The program was subsequently extended to planetary research by participating in experiments at the NASA pioneer Venus project (launch 1978). 5

The Astronomy/Astrophysics program was started with the ESRO astronomy satellite TD-1 (launch 1972) and the satellite to measure the cosmic radiation COS-B (launch 1975).

Current program

The current program is characterized by an extremely good continuity of the program planning. It is very extensive with respect to the fields of expertise and also offers a satisfactory work load for the scientific groups involved in the program. It can look back on many successes and is internationally recognized. It has become one of the most important and indispensable elements of basic research in the FRG. This will be made clear in the following pages which describe the current projects of the individual, scientific fields.

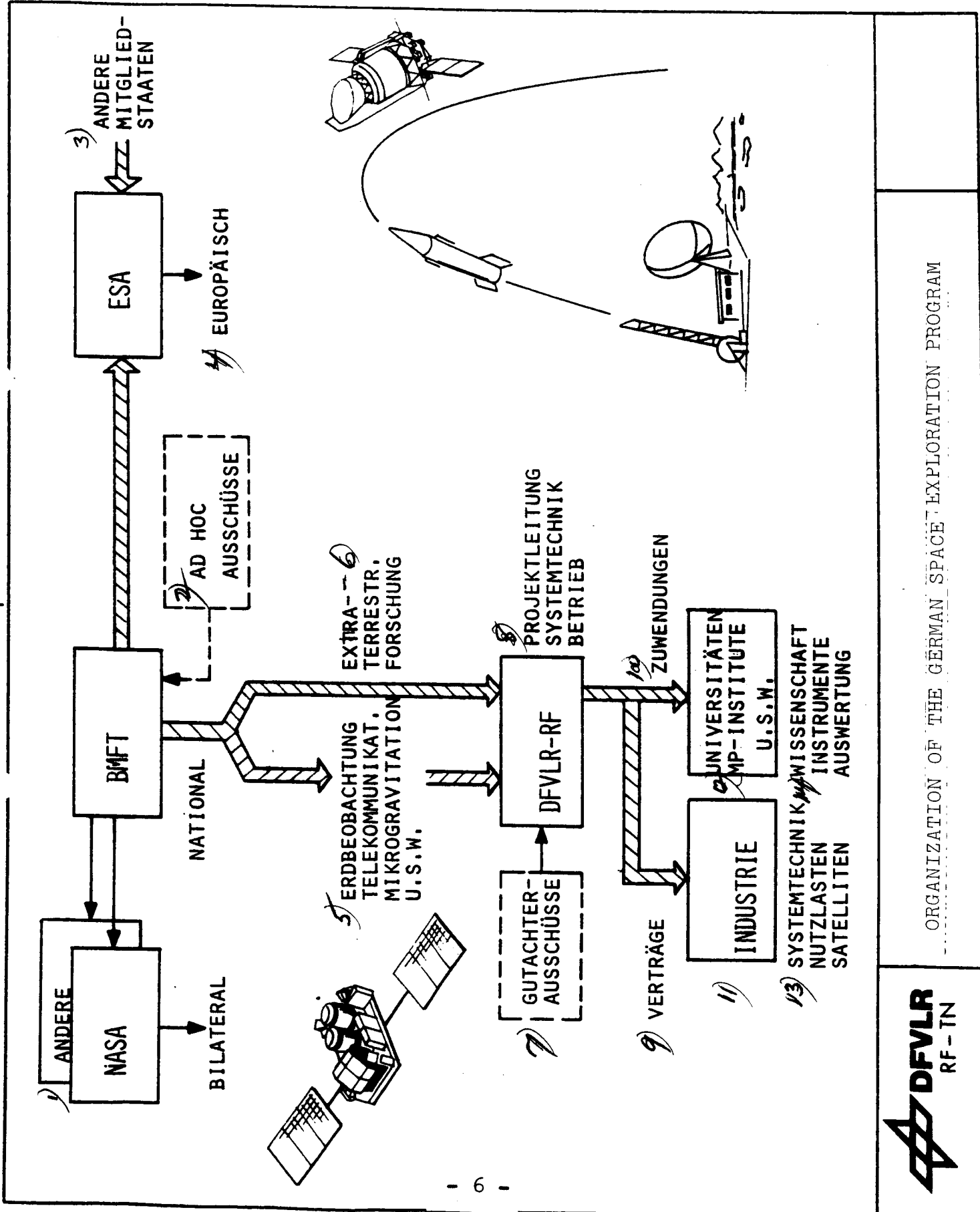


Figure 1

Astronomy, astrophysics (refer to Fig. 2)

Up to recent times astronomers could only make observations from earth through spectral windows as allowed by the earth's atmosphere, i.e. in the visible range and in the range of radio waves. It was space exploration by means of high altitude research rockets and satellites which permitted the deployment of instruments outside the earth's atmosphere and thus made possible measurements of all other spectral ranges. High-flying airplanes and balloons had already brought about some increases of usable spectral ranges.

Fig. 2: Space research in the Federal Republic of Germany

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- 1) Energy 2) Radiation range 3) Infra-red
- 4) X-rays 5) Gamma-rays 6) Wave length
- 7) 1 m telescope on free-floating platform 8) HFR
- projects ASTRO (BMFT) 9) A 1/2 at x-ray range (1975)
- 10) A 3/5 at UV range (1974)
- 11) A4 at x-ray range (1979) 12) A6 at UV range (1976)
- 13) A7 at IR to UV range (1975)
- 14) A8 at x-ray range (1977)
- 15) Astronomy

ASTRONOMY, survey

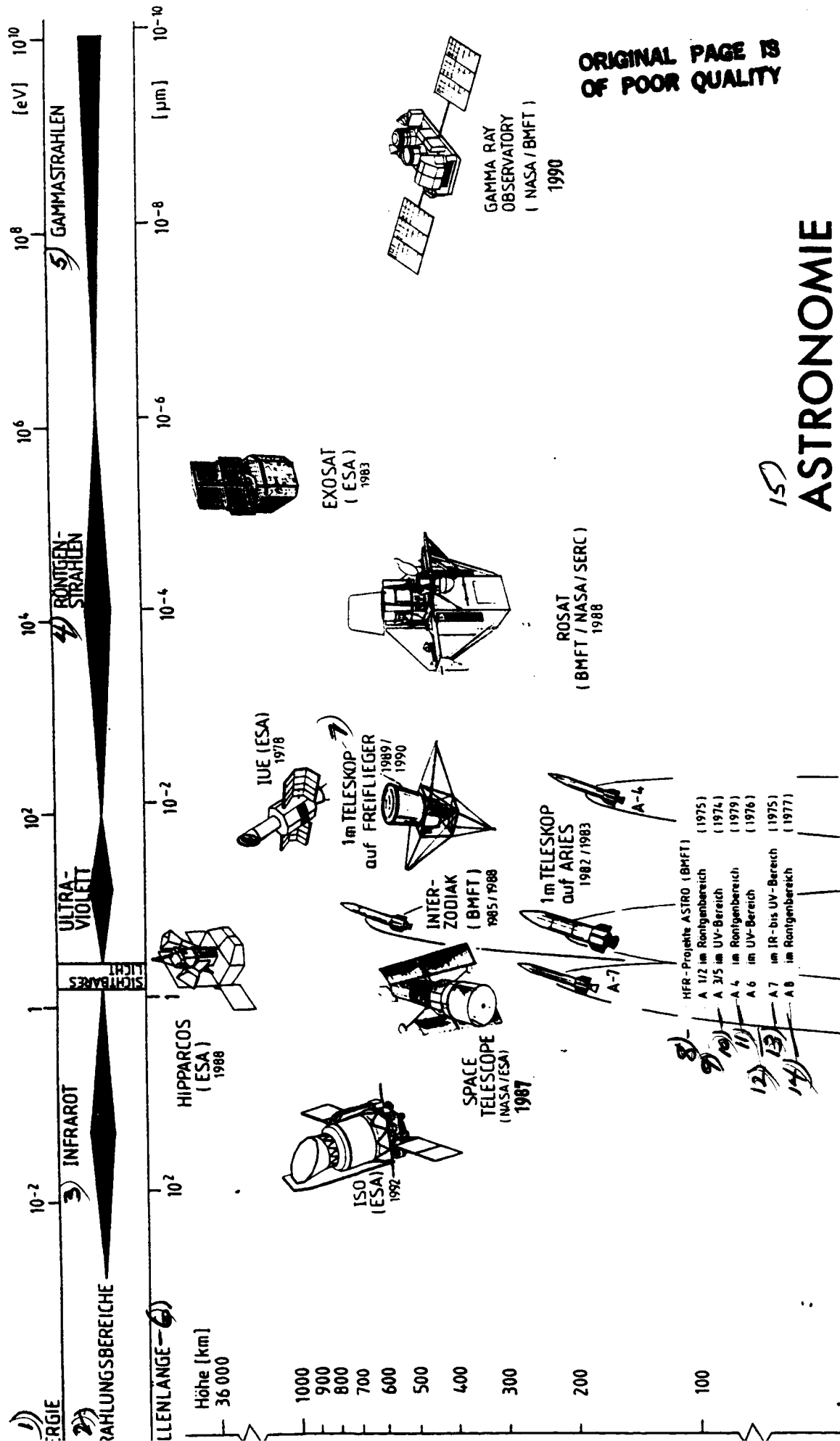
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Range of gamma-rays

Following the scientific results evaluation of the successful COS-B-satellite German scientists are now also participating with two telescopes at NASA's Gamma Ray Observatory (GRO).

X-ray range

Data gained from the observation program of the European x-ray satellite EXOSAT (ESA) is being evaluated. Development and construction of the x-ray satellite ROSAT (trilateral with SERC/UK and NASA) are far advanced (launch due to Challenger disaster still uncertain).



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ASTRONOMIE

— FORSCHUNG

Range of ultra-violet rays

The high-altitude research rocket (HFR), project 1 m EUV telescope, carried out in close cooperation with NASA and INTERZODIAK has already been successfully concluded. German scientists are taking part in the evaluation of the IUE (International Ultraviolet Explorer) - satellite (ESA/NASA).'

Visible range

The ESA participation in NASA's Space Telescope project (launch still uncertain due to Challenger disaster; 1987?) will also offer to German scientists unique observation possibilities. The ESA astronomy satellite Hipparcos (launch 1988) will serve to determine the exact locations of stars.

Infra-red spectral range

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The Infrared-Satellite-Observatory (ISO) of ESA with a planned launch in 1992 will open up this spectral range to German scientists who will supply a large number of focal instruments.

Major projects with strong German participation are outlined in more detail in the appendix:

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INTERZODIAK	29
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Hipparcos	31
ISO	32

Solar terrestrial relationship, survey

Aeronomy: (Fig. 3)

The new space vehicle project MAC-SINE and MAC-EPSILON are in preparation and scheduled to be launched in 1987. German originated experiments will be carried out on board the US-Italian satellite San Marco (launch end 1986). Another project to study the variability of the intermediate and upper earth atmosphere (CRISTA) is in the development stage.

Magneto-sphere (Fig. 3)

Following the evaluation of data from the successful satellites ISEE (NASA, ESA, BMFT), GEOS (ESA), AMPTE (BMFT, NASA, SERK) scientists are now preparing their respective portions for the CLUSTER satellite of ESA. New space vehicle projects such as ROSE (Rocket and Scatter Experiments) are planned once the CAESAR projects have been completed.

The appendix gives more details for projects with strong German participation:

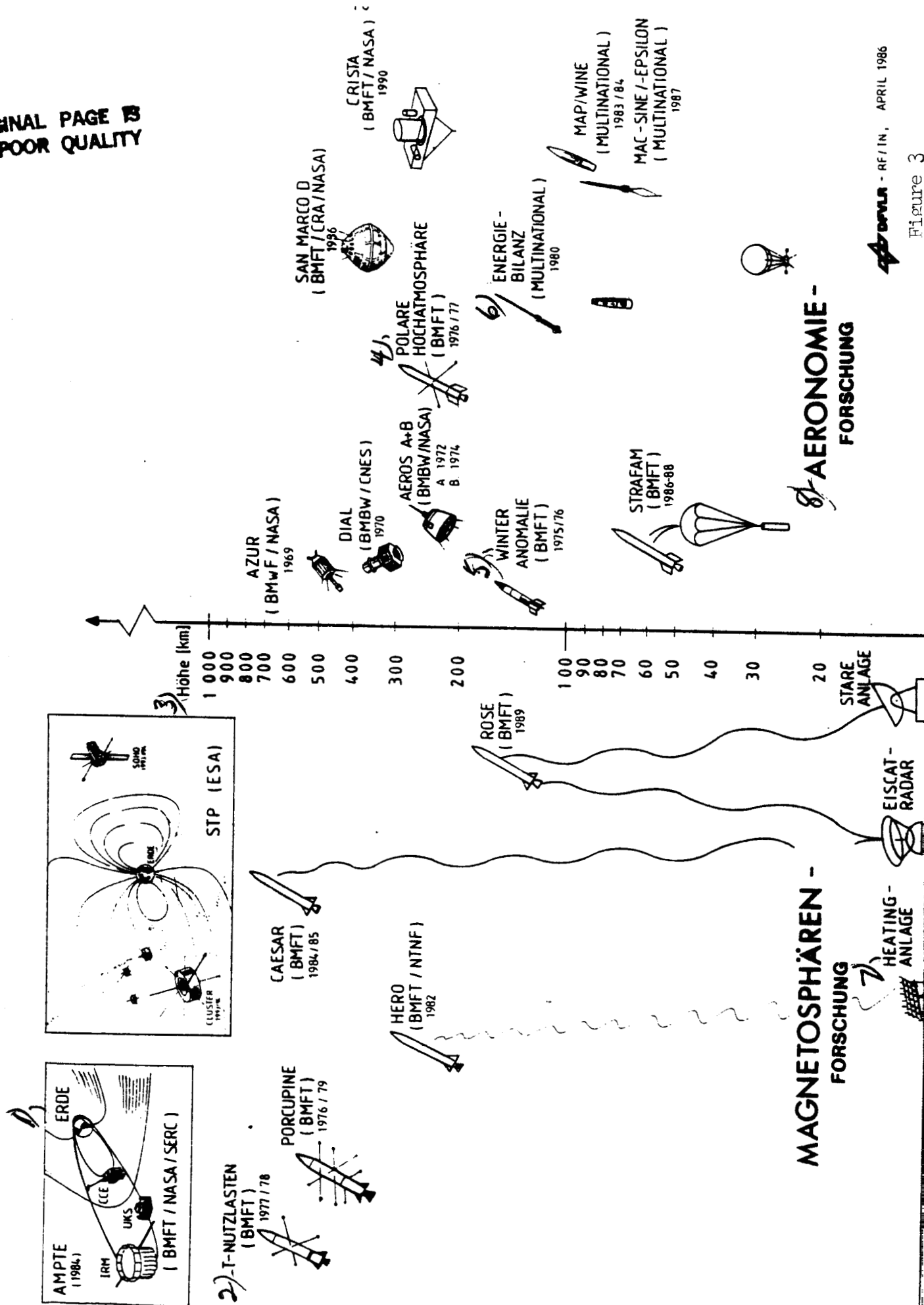
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SAN MARCO	35
CRISTA	36
ISEE/ICE	39
CAESAR	39
AMPTE	42

Fig. 3: Space Exploration of the FRG

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- 1) earth 2) T-payloads 3) height 4) upper polar
atmosphere 5) winter anomaly 6) energy household
7) heating plant 8) aeronomic exploration

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Experiments on board Ulysses (ESA, observation of solar pole areas) and participation in the Jupiter probe project Galileo (NASA) will be delayed since launching cannot take place before the middle of 1987 due to the Challenger accident. The comet probe GIOTTO of ESA was launched in 1985 and reached the closest point to Comet Halley on 3.13.1986. Data evaluation of the solar probe HELIOS, operating successfully for 11 years, will be brought to a conclusion in the near future.

The appendix shows more details for:

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Project and Program costs

Table 1 shows the cost and participants in the major projects.

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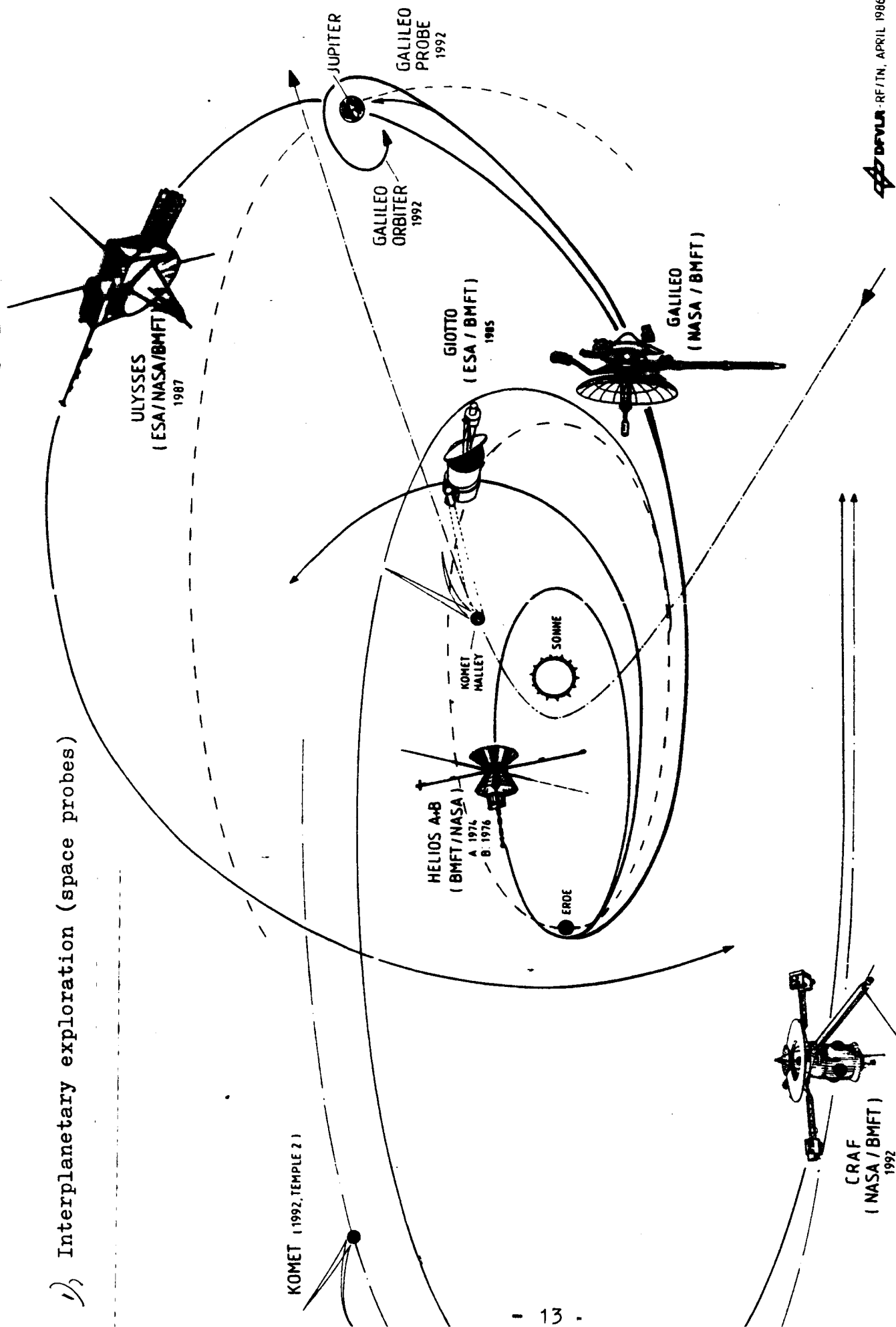
Table 2 shows the financial expenditure of the BMFT for the period from 1980 to 1990 to which must be added the internal means made available by institutes and the DFVLR.

We wish to stress here that the German delegation at the Ministerial meeting in January 1985 made every effort to increase the means of ESA's science program by an annual 5% for the years up to 1989."

Future tasks, intermediate orientation

It is important for the continuity of the program planning to adhere to the present program structure, i.e. participation in ESA's science programs, the acceptance of participation in the

1) Interplanetary exploration (space probes)



CURRENT PROJECTS FOR EXTRATERRESTRIAL EXPLORATION BASED ON

FINANCES, TITLE NUMBER:

68 501, 89 320, 68 601 (TOTAL COST)

<u>Bilateral/national</u>	<u>BMFT</u> expenditure	<u>total</u> cost	<u>European</u>	<u>BMFT</u> expenditure	<u>ESA-</u> costs
	<u>MDM</u>			<u>MDM*)</u>	<u>MDM**)</u>
• HELIOS	435	555 MDM	• ISPM/ ULYSSES	28	296
• GALILEO	77	800 M\$ US	• GIOTTO	37	350
• ROSAT	241	450 MDM	• EXOSAT	2	513
• VOYAGER I u. II	1	460 M\$ US	• ISO	70	593
• GRO	54	964 MDM	• HIPPARCOS	8	660
• AMPTE	15	120 MDM			
• HFR-Program	ca. 6/ year				

*) national contribution to experiments

**) BMFT portion thereof 25%

National cost of other member states
not known

US program as offered by NASA as well as the maintenance of national complementary programs.

Furthermore it will be necessary to achieve a well-balanced mixture of long-term and short-term programs (e.g. space vehicles) in order to offer the scientific community realistic employment (Max Planck Society: scientists with long-term employment contracts, no obligation for apprenticeship; universities: high personnel turnover, short-term contracts, obligation to education and apprenticeship). The program which up to now was carried out with unmanned space flights will in future also include manned missions or manned missions for maintenance and repair.

Table 2:

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- 1) BMFT budget for extraterrestrial exploration
 - 2) means available under title # 3) actual expenditure
 - 4) available 5) budget planning 6) total (national)
 - 7) contributions to the ESA science program, title # 686 01
 - 8) grand total 9) explanation: All figures are rounded.
- The actual expenditure between 1980 - 1983 includes contributions to the ARIANE project.

Since changing orbits will be required, especially for in situ measurements, it will be necessary to use non-reusable carrier systems such as ARIENE or the space shuttle.

With respect to space vehicle concepts the program will continue to include research rockets, satellites and probes and, especially important for astronomy, reusable space shuttles (at a later stage space station platforms) with the potential to return loads to earth. Furthermore, space stations will be required for use as laboratories, maintenance and repair.

The concept of future ground segments will draw on the experience gained from the US relay satellite system TDRSS. Its operating cost will be a definite decision-making factor.

1) Förderung der extraterrestrischen Forschung durch den BMFT

2) Vorhaben aus Haush.- titel	3) I s t a u s g a b e n					4) Ansatz					5) F i n a n z p l a n u n g				
	1980 MDM	1981 MDM	1982 MDM	1983 MDM	1984 MDM	1985 MDM	1986 MDM	1987 MDM	1988 MDM	1989 MDM	1990 MDM	insgs. MDM			
Tit. 685 01	28	28	37	43	39	33	42	44	45	47	48	434			
Tit. 893 20	12	17	28	27	45	90	56	43	48	59	64	489			
Summe: (National)	40	45	65	70	84	123	98	87	93	106	112	923			
7) Beiträge zum ESA-Wissen- schaftspro- gramm	63	64	66	72	69	74	79	91	100	111	123	912			
Tit. 686 01															
8) Gesamt:	103	109	131	142	153	197	177	178	193	217	235	1 835			

9) Erläuterungen: Angaben sind gerundet, die bei den Istaussgaben von 1980-1983 gekennzeichneten Beträge verstehen sich einschließlich eines Anteils für ARIANE.

Future programs

An essential part of the German program for extraterrestrial exploration will be realized within ESA's scientific program. The long-term scenario "Horizon 2000" as submitted by ESA's chairman, Prof. Luest, assisted by many European and, of course, German scientists, is an extremely helpful document also for national planning.

In the field of astronomy and astrophysics a new generation of large-scale telescopes in space will be the dominant exploratory instruments in the next decade. This equipment will benefit from the availability of space station supplies (long-term platforms for maintenance and repair).

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Next to NASA's Space Telescope NASA also has plans for an Advanced X-Ray Facility (AXAF), an Infrared Telescope SIRFT (at the end of the 90's) and a Solar Telescope. European or German participation is possible and planned. ESA has plans within the framework of the long-term program, Horizon 2000, for an Infrared Satellite ISO, the "FIRST", an observatory for the extreme infrared spectrum and for QUASAT for "Radio Very Long Baseline Interferometry" as well as for a large UV-telescope "Lyman" and a large x-ray observatory in cooperation with NASA.

Such large-scale projects require substantial investments and may be too expensive as national or bilateral projects. They should, therefore, be realized in conjunction with NASA. The focal instrumentation of such devices, made by various ESA members, will have to be financed within the framework of national programs.

Projects of the size of ROSAT and areas not covered by ESA and NASA programs may be carried out at the national level as complementary programs. It is intended as a first step for a space-station-compatible platform for scientific studies, to use a platform based on SPAS, ROSAT and EURECA. Such platforms for astronomical and aeronautical missions should be realized in conjunction with NASA (will forego launching cost). First discussions with NASA have already begun. Potential payloads include 1 m EUV telescope for UV-astronomy.

The field of solar-terrestrial relationship requires in situ measurements at various locations in space as well as measurements from a distance. This will be achieved by a small satellite program (frequently in large numbers) but also by planet-asteroid and comet probes.

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As an example, we wish to mention the ESA planned SOHO and CLUSTER program the first so-called "Cornerstone" of the Horizon-2000 program. This program is to carry out magnetospheres/plasma studies. The total investment in these programs is rather high but due to the relatively small size of the individual components (satellites) there exists the possibility of participation by other nations (e.g. Japan and USA).

Programs for planet, comet and asteroid probes are so costly that they should only be undertaken by either ESA or NASA or as a common venture. German participation in the NASA-planned programs such as "Comet Rendezvous and Asteroid Flyby" (CARF) seems feasible on the same basis as for the GALILEO project. Such missions planned by the NASA solar system exploration program could partially use space stations as intermediate stops. Experiments for such missions are continued on a national basis.

Aside from the large-scale enterprises, the solar-terrestrial field will in future continue to require high altitude programs in conjunction with ground and satellite measurements (e.g. MAC-SINE-EPSILON).

In summarizing one can say that the German extraterrestrial program covers many areas as far as the intermediate future is concerned. This applies to the many expert fields of the various German scientific groups as well as to the extent of study so that a similar continuation provides good prospects for the future.

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ESA's science budget was increased, mainly due to German initiative, by about 5% per annum at the Ministerial meeting in Rome at the end of January 1985. The Rome agreement provides annual increases of 5% p.a. until 1989. The FRG supports the long-term program "Horizon 2000" with annual contributions of 200 MAU. The level of spending

will be reached in 1994 and is incorporated in the intermediate budget plans. It will offer a more extensive level of participation to German scientists. Of course there have to be similar expenditure increases on the national level since payloads are based on national programs.

The same applies to the preparation of experiments and instrumentation which will be deployed at space stations in the mid-90s.

A major factor for planning and guarantee of success is not necessarily the absolute size of the budget but the assurance and continuity of finances over long periods of time, since the German program is part of an international long-term program, and scientific and expert communities cannot be created or disbanded at random.

The appendix presents more details of some of the ventures, such as SOHO, CLUSTER and CRAFT.

Conclusion

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The German program for basic extraterrestrial research is an essential, successful and world-wide recognized part of the space program and has the same attributes for basic research in the Federal Republic of Germany. It covers all major scientific disciplines.

A quality comparison on an international level can be made with, e.g. the successful solar probe HELIOS as well as with offers of cooperation by other nations, e.g. the USA. Furthermore a disproportional involvement by German scientists in ESA projects is also a yardstick for the ability of German institutes and the German space industry. The German program uses the possibilities of the ESA science program and cooperation offered by other organizations such as NASA. Supplementary, national programs produce a well-balanced, all-encompassing, long-term master program which offers the various scientific sectors focal points at different time intervals.

The BMFT has offered further appropriate support for the space program of the FRG.

APPENDIX

Description of individual projects:

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Planets, Interplanetary space

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The Gamma Ray Observatory (GRO) is a NASA project to study the range from soft to hard gamma rays. The FRG plays an essential part in two of the four experiments (Fig. 2.1). Cooperation between BMFT and NASA has been outlined in a letter agreement of September 1981.

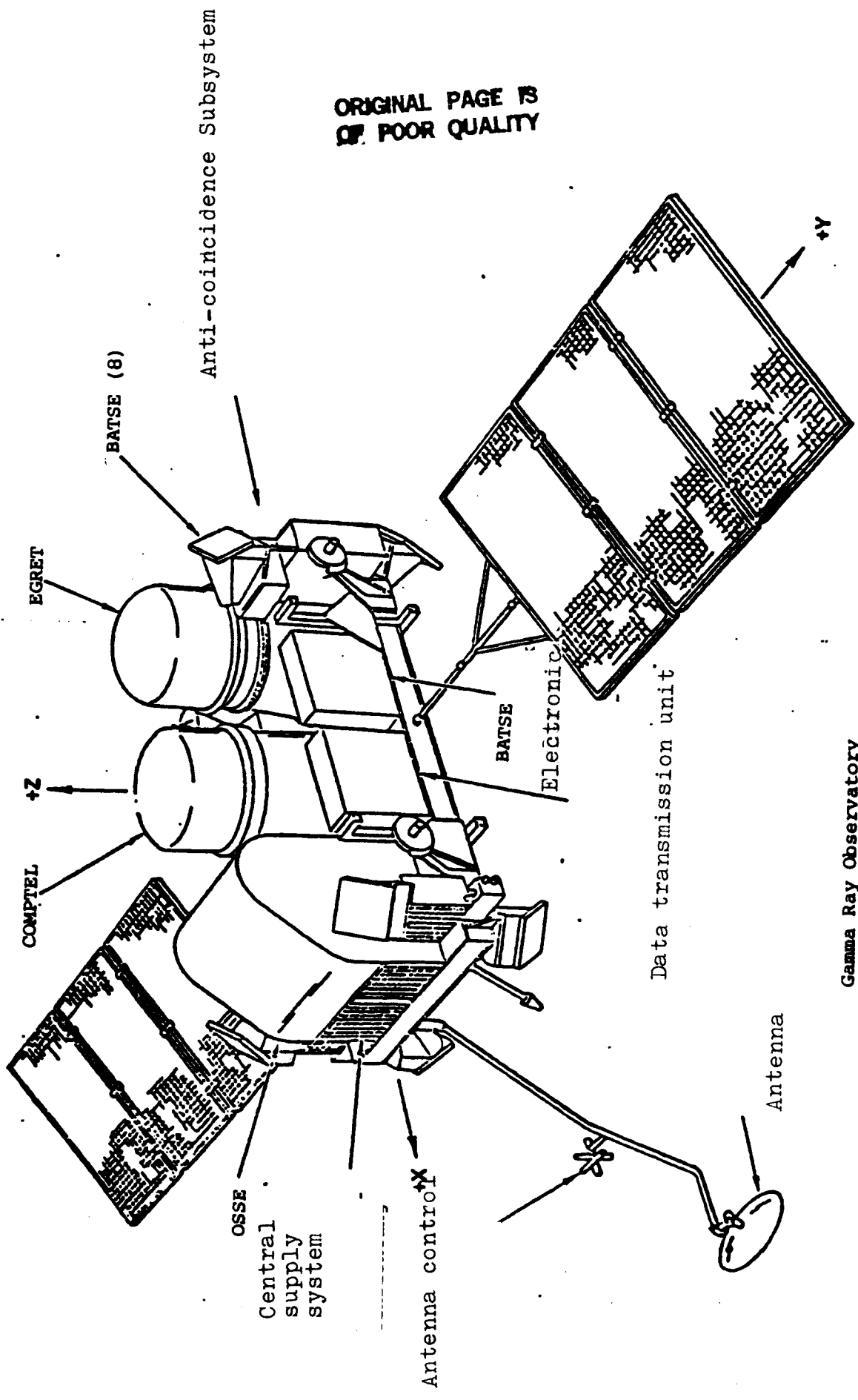
COMPTEL (Compton Telescope), one of the three large experiments, is being developed under German management and constructed at the MBB company. Other participants in the soft gamma ray experiment are the research institute of the New Hampshire University, USA, ESA-ESTEK and the Leiden University, both of the Netherlands.

The Principal Investigator (PI) comes from the Max-Planck Institute for Extraterrestrial Research in Garching, near Munich. Each institute provides essential hardware.

COMPTEL (Fig. 2.2) uses the Compton scatter (gamma rays at electrons) to register the gamma radiation. It is planned to measure the energy range between 1 and 30 MeV. The experiment alone will have a weight of 1.4 tons while the complete satellite will exceed 15 tons.

The major scientific goal of COMPTEL is the discovery of point sources, the study of diffuse gamma emission and the gamma line spectroscopy.

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Gamma Ray Observatory

Dimension: 8 m x 4 m x 4 m (without solar cell)

Figure 2.1

COMPTON Detector, design and subsystems

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Cable shaft

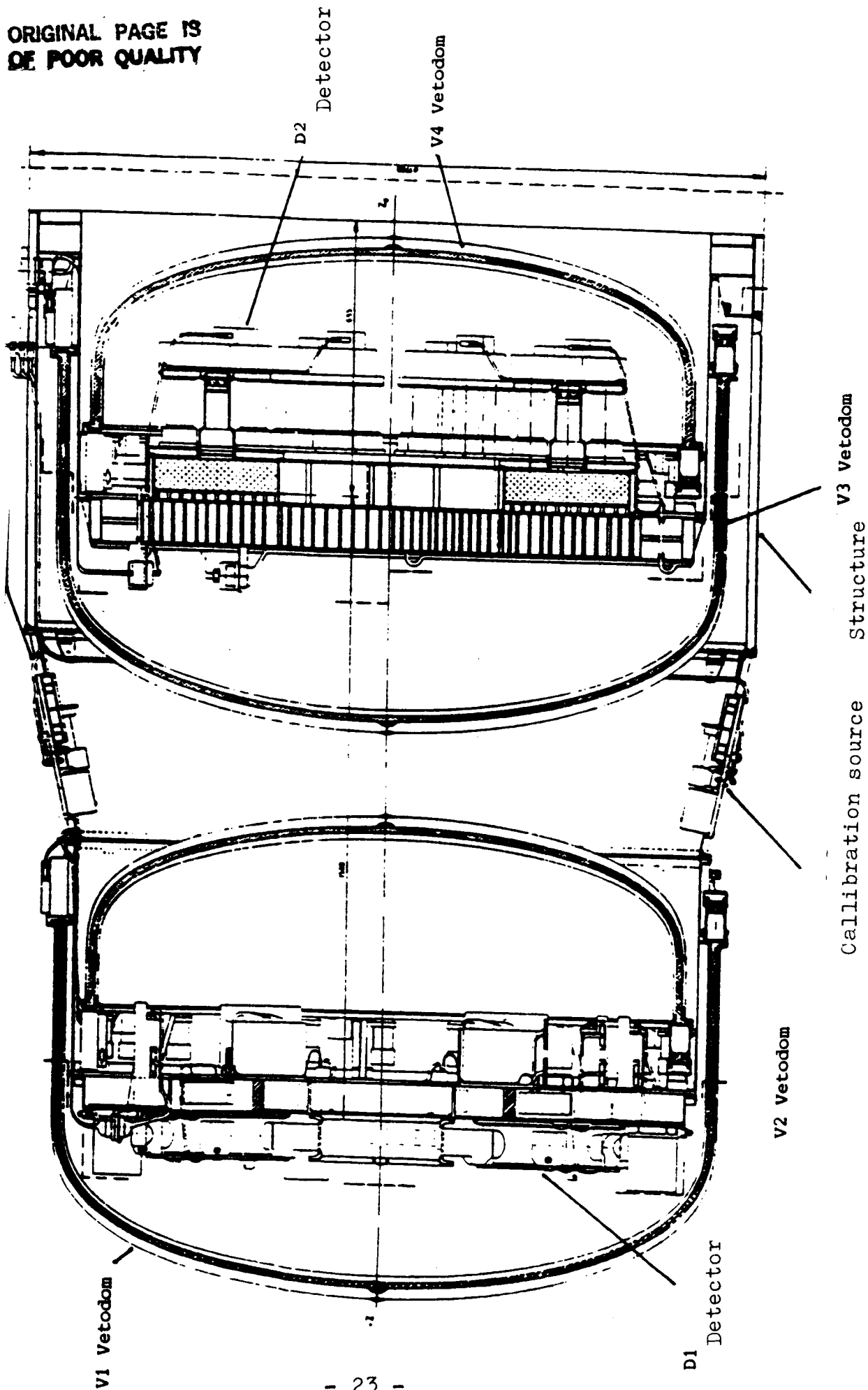


Figure 2.2

GRO - EGRET

The second instrument on GRO, in which German scientists are also involved, is EGRET (Energetic Gamma Ray Experiment Telescope) (Fig. 2.3).

It will serve to observe high-energy radiation. The sensitivity as well as the resolution capability of this telescope will exceed the values of former experiments and satellites (e.g. COS-B) by a magnitude of ten in the energy range above 20 meV.

EGRET is being developed by the Goddard Space Flight Center (GSFC) of Stanford University, the Gruman Aircraft Corporation and the Max Planck Institute for Extraterrestrial Physics as a joint venture. GSFC will supply the spark chamber with trigger device; Stanford, the energy calorimeter for determining the photon energy while the Planck Institute is responsible for building the anti-coincidence system and the pressure container for the spark chamber.

According to recent plans COMTEL and EGRET are scheduled to be launched on board GRO by the NASA space shuttle in February 1990. It is to have an orbit close to earth at about 450 km height.

Fig. 2.3

- 1) View of "Energetic Gamma Ray Experiment Telescope" (EGRET)
- 2) outer diameter
- 3) light visor
- 4) sealed electronics container
- 5) anti-coincidence scintillator dome
- 6) upper spark chamber
- 7) upper scintillator, light duct and photomultiplier
- 8) lower spark chamber
- 9) anti-coincidence photo multiplier
- 10) pressure vessel
- 11) lower scintillator, light duct and photomultiplier
- 12) base plate
- 13) electronics container
- 14) gas replenishment system
- 15) NA I crystal

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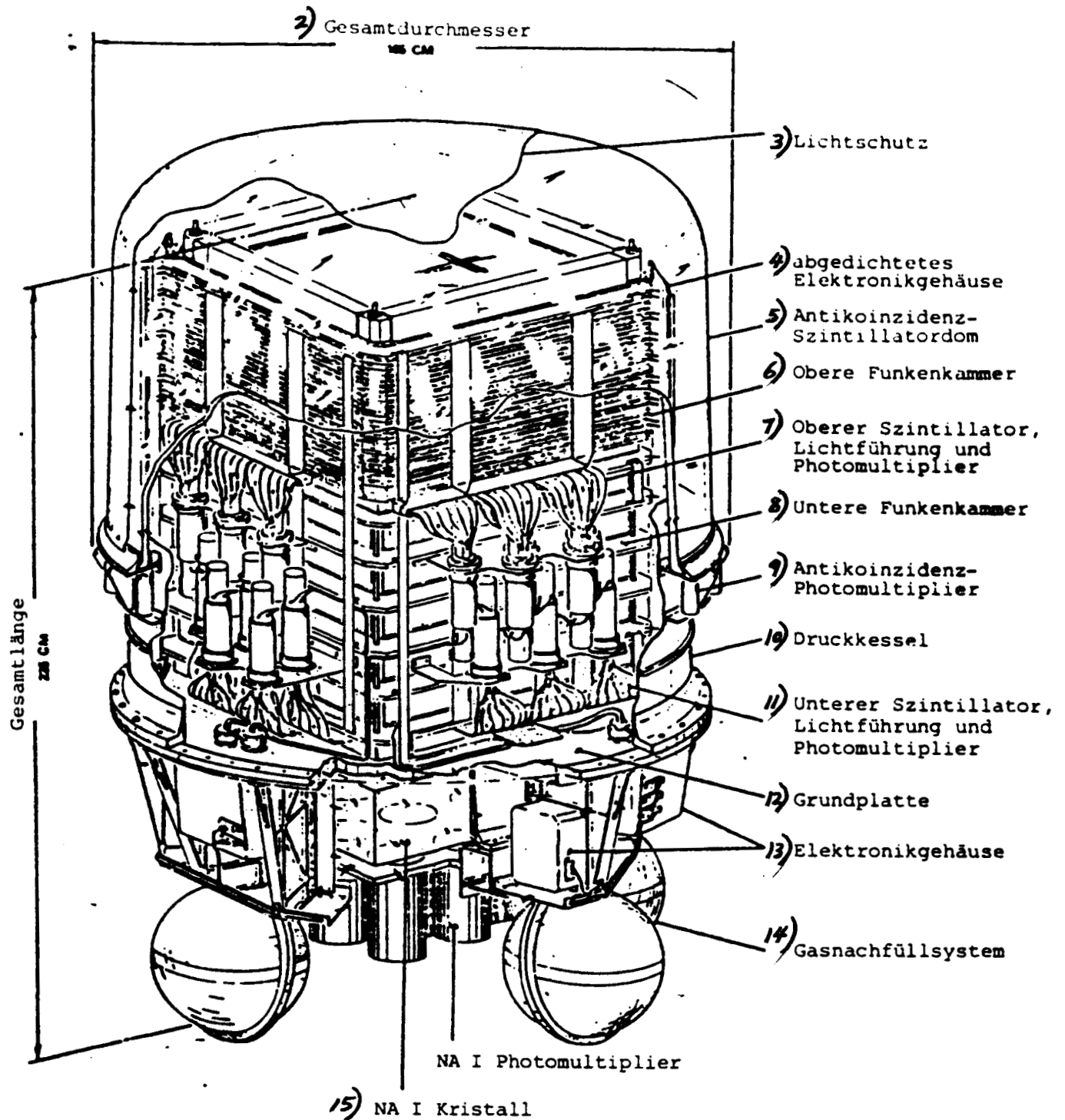


Figure 2.3

1) Ansicht des "Energetic Gamma Ray Experiment Telescope" (EGRET)

Following AZUR, DIAL, AEROS and HELIOS the x-ray satellite (ROSAT) will be the fifth scientific satellite project of the FRG.

Based on optical principles discovered by the German physicist, Hans Wolter, a four-shell x-ray telescope is being developed with a focal length of 2.40 m and a mirror diameter of 80 cm. It will operate in a free-floating space vehicle. Two point sensitive proportional counter (PSPC) and a high resolution imager (HRI) will be used in the focal plane of the telescope to study cosmic x-ray quanta. The PSPC is being developed in Germany while the images are being supplied by NASA.

Also on board will be a small English telescope which will expand the wave length towards EUV.

The goals of the x-ray satellite mission are:

- to obtain for the first time complete sky pattern data by using an x-ray telescope with a point accuracy of x-ray sources of better than one arc minute
- to study in detail selected x-ray sources (pointing) with regard to structural shape, changes caused by time as well as their spectral characteristics.

It is expected that the resulting pattern will reveal the existence of several hundred thousand x-ray sources. The data will then be summarized in an x-ray atlas. The x-ray satellite will be available as an observatory to many interested scientific groups during the pointing phase.

It is planned to launch the x-ray satellite with the NASA space shuttle. The nominal mission length is to be at least 18 months.

The major technical data of the satellite is:

Mass	2.8 tons
Dimensions	2.2 m length
	4.5 m diameter

Solar generator capacity	1 kW
Data storage capacity on board	1 400 Mbit
Data transmission rate	1 Mbit/s

The x-ray satellite development has almost been completed following the integrated system test on a development model. A critical design check based on test results and analytical evaluation showed that requirements have been or can be met.

The project is based on international cooperation together with the USA and Great Britain. The BMFT has assigned the project management to the DFVLR in Cologne. In exchange for accommodating an American instrument and participation in the observation period NASA will provide a free-of-charge launch of the satellite with the space shuttle. Launching the flight model is planned for the middle of 1988, mission control with the ground control station of the DFVLR in Oberpfaffenhofen.

Management of the scientific data evaluation lies with the Max Planck Institute for Physics and Astrophysics in Garching.

1 m EUV - Telescope

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This bilateral space vehicle project (Germany/USA) will undertake astronomical measurements on selected stellar objects at the far and Extreme Ultraviolet (EUV) range under the scientific direction of Prof. M. Grewing of the Astronomy Institute, Tübingen University, and Prof. S. Bowyer, Space Science Lab (SSL), University of California, Berkeley, USA.

Prior to EUV experiments were photometric experiments, whereas for the first time this study will be based on a spectroscopic payload. Spectroscopy will make it possible to gain new insights into the dynamics and composition of the outer layers of star atmospheres as well as interstellar media. Two missions with a 1 m mirror telescope for the EUV range aboard an ARIES rocket were launched on 6.17.1982 and 11.27.1983 at White Sands Missile Range, USA.

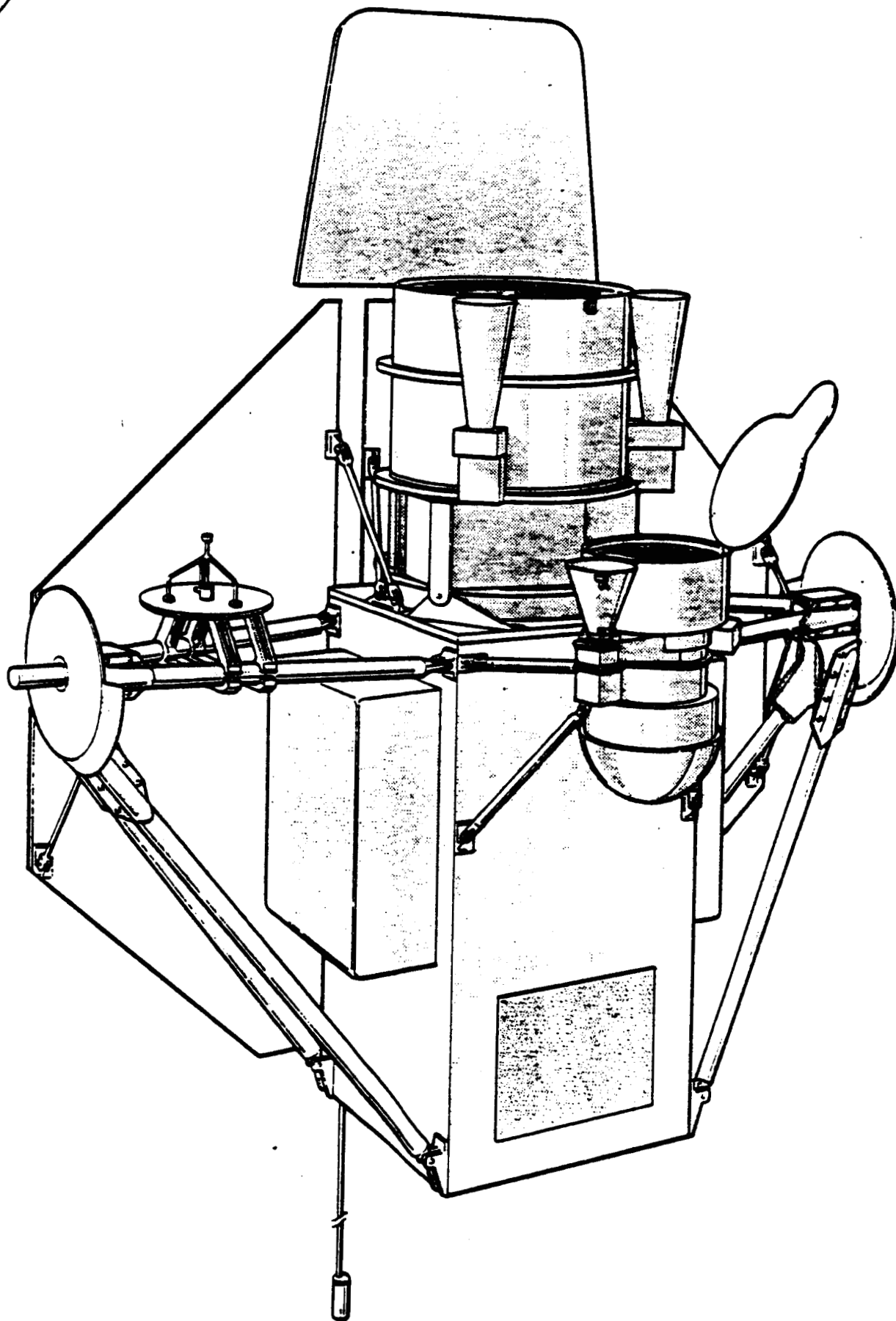


Fig. 2.4

The focal plane of the telescope incorporated a Rowland spectrometer with medium resolution (SSL) and a combination of six photometers (AIT). The mission target in both cases was the hot White Dwarf Hz 43 at the extreme UV (35 - 110 nm) and the photometric study of diffuse, extrasolar background radiation of the extreme and far UV (75 - 220 nm).

The project's long-term goal is the use of a 1 m mirror telescope on a free-floating platform to be released from a space shuttle, recaptured and brought back during the same mission. It is hoped that this will produce considerably more integration time which is required for recording stellar objects in the EUV range.

INTERZODIAK

The INTERZODIAK project is regarded as the successor to the ASTRO 6 and ASTRO-HEL projects which were successfully completed in June 1976 and October 1979. 31

INTERZODIAK, like the two prior projects, is to analyze the helium radiation at the still closer vicinity of the sun as well as the radiation of the geo-coronal hydrogen. The particular scientific goal of this project is the study of a specific type of EUV radiation which is created as resonance radiation of solar photons as neutral gas particles in the close vicinity of the solar corona.

One payload was launched at Natal, Brazil on 3.3.1985, a second one being planned for March 1988.

Prof. H.J. Fahr, Institute for Astrophysics and Extraterrestrial Research, Bonn University, was the scientific director of this space mission.

The payload can be adjusted in three axial planes as demanded by the complicated directional requirements. It will be protected while passing through the thicker atmosphere by a disposable nose cone.

The payload was designed and built by the Dornier Systems Company. The directional bearing control was designed and supplied by the DFVLR. The three-stage rocket, type Skylark 12, was delivered by the British company BAE.

Such a cooperative project is a typical example of the development of a payload from the early testing of rockets to the complicated deployment of a space station and satellite.

32

IUE - Satellite

The International Ultraviolet Explorer (IUE) Program involves cooperation between NASA, ESA and the British Science Research Council (SRC).

It was the scientific goal of the International Satellite Program IUE to provide an orbital observatory for the UV spectral range. It is being operated by two ground stations, i.e. NASA/GSFC (USA) and Villa Franca (Spain) at a geo-stationary orbit.

The major stress of the IUE research lies in the UV range between 1150 and 3200 Å. The satellite was equipped with one 45 cm Cassegrain telescope, two Echelle spectrographs and two TV detector cameras. Its launch weight was 670 kg. The launch took place on January 26, 1978. It was designed for an operation period of three years and is still operating satisfactorily after eight years. It is planned to continue the mission until 1990.

The FRG takes part in this project via ESA. Based on their financial involvement NASA is given 16 hours/day of observation time and SRC and ESA each 4 hours/day.

At the beginning of the mission 200 astronomers from 17 nations (including the USSR) were named who were to undertake astronomical IUE observations. The scientific studies reached from the planets of our solar system to the furthest object of the universe, including quasars, pulsars and black holes.

Hipparcos (High Precision Parallax Collecting Satellite) is meant to honor the Greek astronomer Hipparch (ca. 150 B.C.) It is an ESA project. The instruments aboard the astrometry-satellite are designed to obtain exact data of trigonometric parallaxes, location and axial movement of about 100,000 selected stars, the majority brighter than the 11th photographic size, all of which takes place over a period of $2\frac{1}{2}$ years. It is hoped not to exceed the mean error of parallaxes by $\pm 0''002$ per year. The principle behind the study with Hipparcos is the precision measurement of an angle of 68.5° between two selected pairs of stars.

It is for this purpose that the telescope has been provided with two radiation receivers each with an aperture angle of 54 arc minutes which includes the basis angle of 68.5° . The images from the two radiation receivers are transposed by means of a complex mirror which allows a differential measurement of the angle differences by comparing star locations.

The launch of Hipparcos is planned for July 1, 1988 aboard an ARIANE 4. The satellite path is scheduled to be geo-synchronous, i.e. the orbit will be tilted away from the equator at an approximate distance of 36,000 km.

The FRG participates in this program via ESA. Furthermore, the Federal Government supports four scientific institutes:

- The Astronomical Institute of the Hamburg University
- The Astronomical Institute of the Bonn University
- The Astronomical Institute of the Tuebingen University
- The Astronomical Computer Institute, Heidelberg.

These institutes will prepare the 100,000 star input catalog and make preparation for the photometric measurements of Hipparcos.

The launch of the ISO satellite is planned for 1992. It involves a telescope which is cooled down to 10 K and which utilizes the spectral range 2 - 200 μm . It has an aperture of 60 cm diameter and incorporates four scientific instruments (Fig. 2.5).

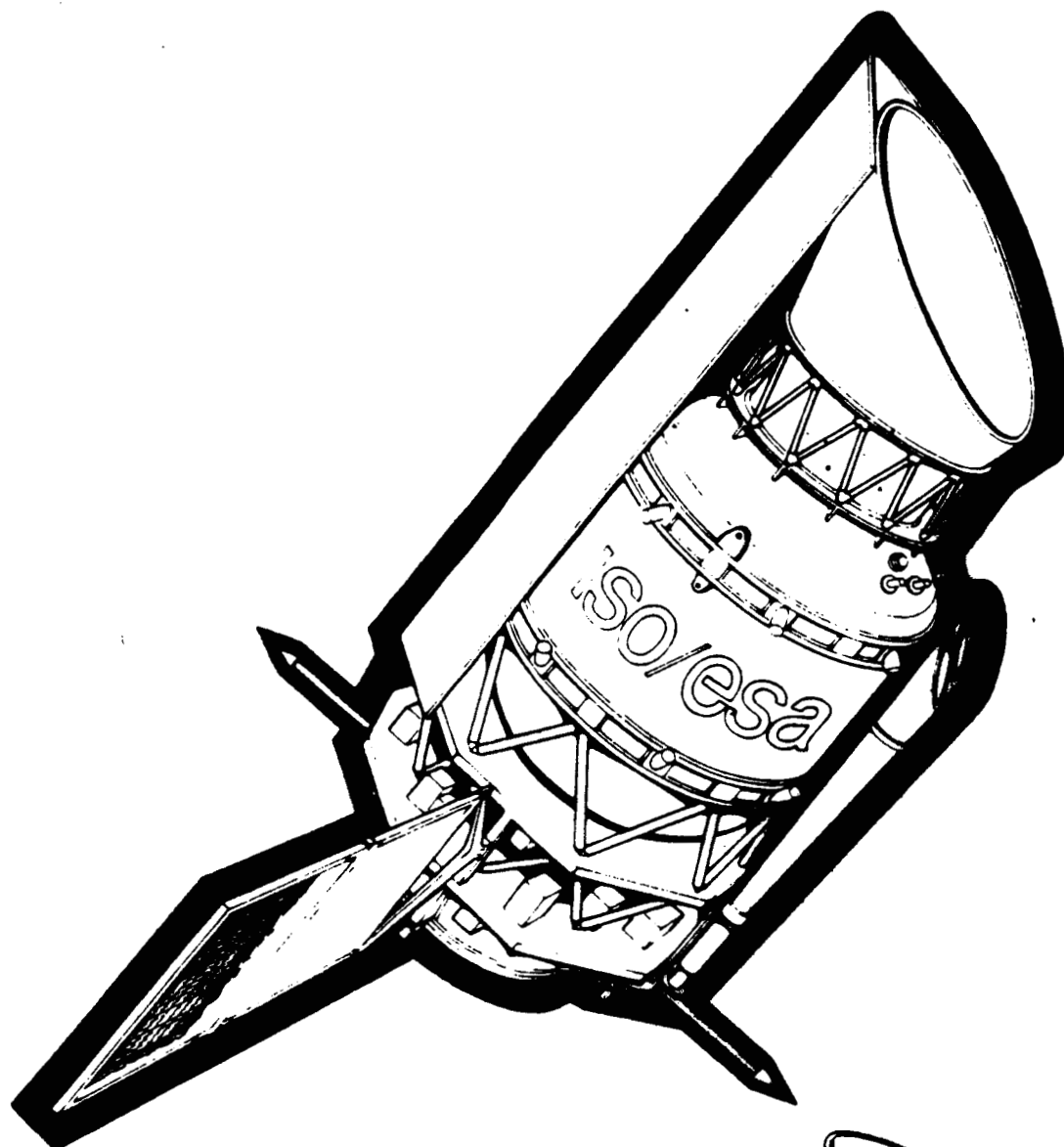
The satellite is being developed by ESA with a large involvement of the German industry. The scientific instrumentation is the responsibility of various international institutes.

The FRG participates in $1\frac{1}{2}$ of the four experiments and supplies the Principal Investigator for the photo-polarimeter.

Compared to conventional IR observations by plane or telescopes aboard balloons, ISO has a 1000 times higher sensitivity due to operation outside the earth atmosphere which eliminates interference. At the same time heat radiation, i.e. internal IR radiation of telescope and instrument is very much reduced by strong cooling, so that the infrared sources of the sky can be studied without instrumental interference.

The telescope is cooled with 2000 l superfluid helium. Extreme insulation measures permit a cryostatic holding period of 20 months which is the planned life span of the satellite. ISO will be launched by ARIANE.

Mainly involved is the study of such astronomical objects whose luminosity lies in the infrared spectrum such as chains of secondary stars and dust clouds as well as cosmo-logical objects such as Seytert galaxies and suspected quasars. Another major investigation is the study of objects which are embedded in dense dust clouds which can only be observed by infrared but not optical astronomy. This includes areas of new star formation, galactic centers and the center of our Milky Way.



INFRARED SPACE OBSERVATORY

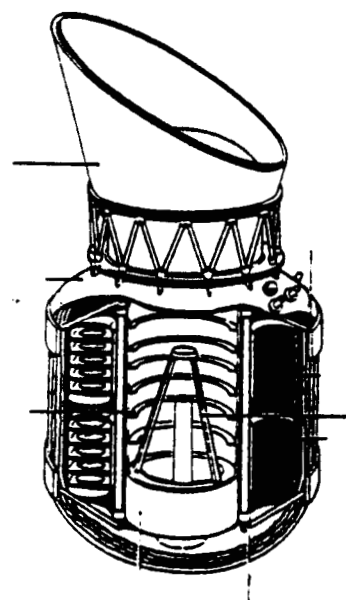


Figure 2.5

The years from 1982 to 1985 involved the Middle Atmosphere Program (MAP) which was very successful in stimulating and coordinating the study of the earth's atmosphere, i.e., the stratosphere, mesosphere and the lower thermosphere. Interest was indeed so lively that the scientific community has recommended continuing MAP with a new program named Middle Atmosphere Cooperation (MAC).

Part of MAP was the Winter-in-Northern-Europe (WINE) campaign carried out successfully between November 1983 to February 1984. MAP/WINE produced many new and valuable data of the high middle atmosphere during a winter period. The experience gained from both experimental technology and theoretical methods will form a solid base for further studies.

These studies are planned to expand into the following directions:

- a) to record the conditions of the middle atmosphere at higher latitudes and other seasons which, of course, have quite different meteorological conditions and
- b) investigation of especially important phenomena which would not be fully studied in earlier campaigns.

The project presently planned provides for two ventures of differing, however complementary, scientific goals:

- Middle Atmosphere Cooperation/Summer in Northern Europe (MAC/SINE) 39
into investigated conditions during summer solstice. This venture should produce the largest contrast to the winter conditions as studied during the MAP/WINE campaign. The venture will consist of a number of regular meteorological rocket launches as well as observations from ground stations.
- MAC/EPSILON (EPSILON stands for energy dissipation rate in atmospheric turbulence) is regarded as a study of turbulences in the middle atmosphere, i.e., a study of phenomena, concentrated in time and space, during strong turbulences. It is also expected to provide new information about the middle atmosphere's general condition at high latitudes during fall

and winter conditions. The venture includes five densely instrumented payloads as well as several meteorological rockets which are launched in certain combinations supported by several ground station observation methods.

The high-altitude rocket research project is undertaken bilaterally with Norway.

The scientific management lies with Dr. E. Thrane, Oslo/N and Prof. U.v. Zahn, Physics Institute of Bonn University. Launches are scheduled in June/July 1987 (SINE) and October/November 1987 (EPSILON) at Andoya, Norway.

San Marco D/4

40

The fourth US/Italian project between the Centro Ricerche Aero-spaziale: (CRA) of Rome University and NASA/GSFC also involves two German experiments aboard the satellite San Marco D/4. This satellite concentrates on aeronomic and radiation equilibrium measurements.

- Aboard the satellite is the device ASSI (Airglow Solar Spectrometer Instrument) which was formerly designed by the Fraunhofer Society (FhG), Munich and is now in the hands of the PTS company in Freiburg. It is being built by the Dornier System Company. The device records in 18 selected wave length ranges the incoming radiation between 70 and 700 nm, i.e. it ranges from the extreme ultraviolet to the optical spectrum. The large dynamic capacity of the channels from $1 : 10^{11}$ permits the simultaneous measurement of simple radiation of weak air glow from interplanetary sources (reflected light from clouds and water surfaces) as they occur during one satellite revolution all the way to the measurement of intensive, unhindered solar radiation - all with one single device.

This device is a direct further development of an experiment used in the AEROS program.

- The second German experiment, the Drag experiment ODA of Bonn University (responsible scientist Prof. Roemer) is to determine the satellite's deceleration through orbital air particle density based on radar data obtained.

Data collected from both experiments, together with the Italian and American experiment, will permit detailed statements about composition, temperature, particle density as well as their dynamic behavior in the equatorial thermosphere (orbit height about 700 km).

41

It is planned to launch the satellite in November 1986 at the launch facility SAN MARCO on the coast of Kenya. The experiment will have a life span of more than 1.5 years.

CRISTA

42

The helium-cooled infrared telescope CRISTA (cryogenic infrared spectrometer and telescope for the atmosphere) is the center piece of a venture to study the variability of the middle and upper atmosphere. It is to investigate medium and small volume structures aboard a free floating platform released from a space shuttle. Previous measurements of atmospheric parameters at heights from 50 - 120 km frequently showed small variations which were regarded as local effects, background noise or measuring problems. Newer results from space research vehicles seem to indicate that the majority of structures are not random by nature. This exploratory mission is to establish to what extent the above variations occur in the atmosphere. A three-day flight mission at 300 km height will make it possible, due to the high resolution, to measure changes in the dynamics, energy balance and molecular composition. The atmospheric layers investigated, 1.5 km thick at heights of 20 - 150 km, will be at a 2000 km distance from the instruments.

Several scientific groups who have previously worked successfully together at some space exploration programs (balance, MAP/WINE) want to join CRISTA in order to "research the atmosphere's

variability". Major contributions are expected from two US Michelson interfero-meters which will, together with CRISTA, cover large parts of the infrared wave length spectrum and which will supplement each other due to their different pointing direction capabilities.

It is planned to carry out the measurements simultaneously with the NASA satellite UARS (Upper Atmosphere Research Satellite) whose measuring ranges will fit into individual sections of the experiment and whose extended measuring period will offer good global cover.

43

A schematic cross section of the CRISTA telescope is shown in Fig. 3.1.

Infrared radiation emitted by the atmosphere enters through three apertures (three point directions) into the instrument. A baffle structure suppresses undesirable scatter radiation. Three telescopes (Herschel type) fix the spatial resolution and focus the radiation onto the spectrometer. A tilting mirror in each telescope allows the sensing of individual height layers. The spectral defraction of the incoming radiation is achieved (separately for each pointing) in grid spectrometers (Ebert-Fastie type). Nine high-sensitivity detectors in each of the three spectrometers record characteristic emission of trace gases. Each detector is arranged in such a way that it can measure a major line or band in the wave length of 4 - 24 μm .

There is an additional spectrometer with four channels (detectors) for the 15 - 80 μm range in the center radiation duct. Detector operation and suppression of internal telescope and spectrometer emission requires cooling with suprafluid helium (2.5 K to 3.5 K) or supercritical helium (5K to 11 K). A tank capacity of 20 l (not shown) and 900 l helium offers an estimated operating time of 20 days (including time span prior to launch).

A stationary GKF cylinder serves as a connection between the cool and warm portion of the device and takes the launching stress of the cryostat. A radiation visor, cooled by waste helium gas, reduces incoming heat radiation through the outer vacuum shell.

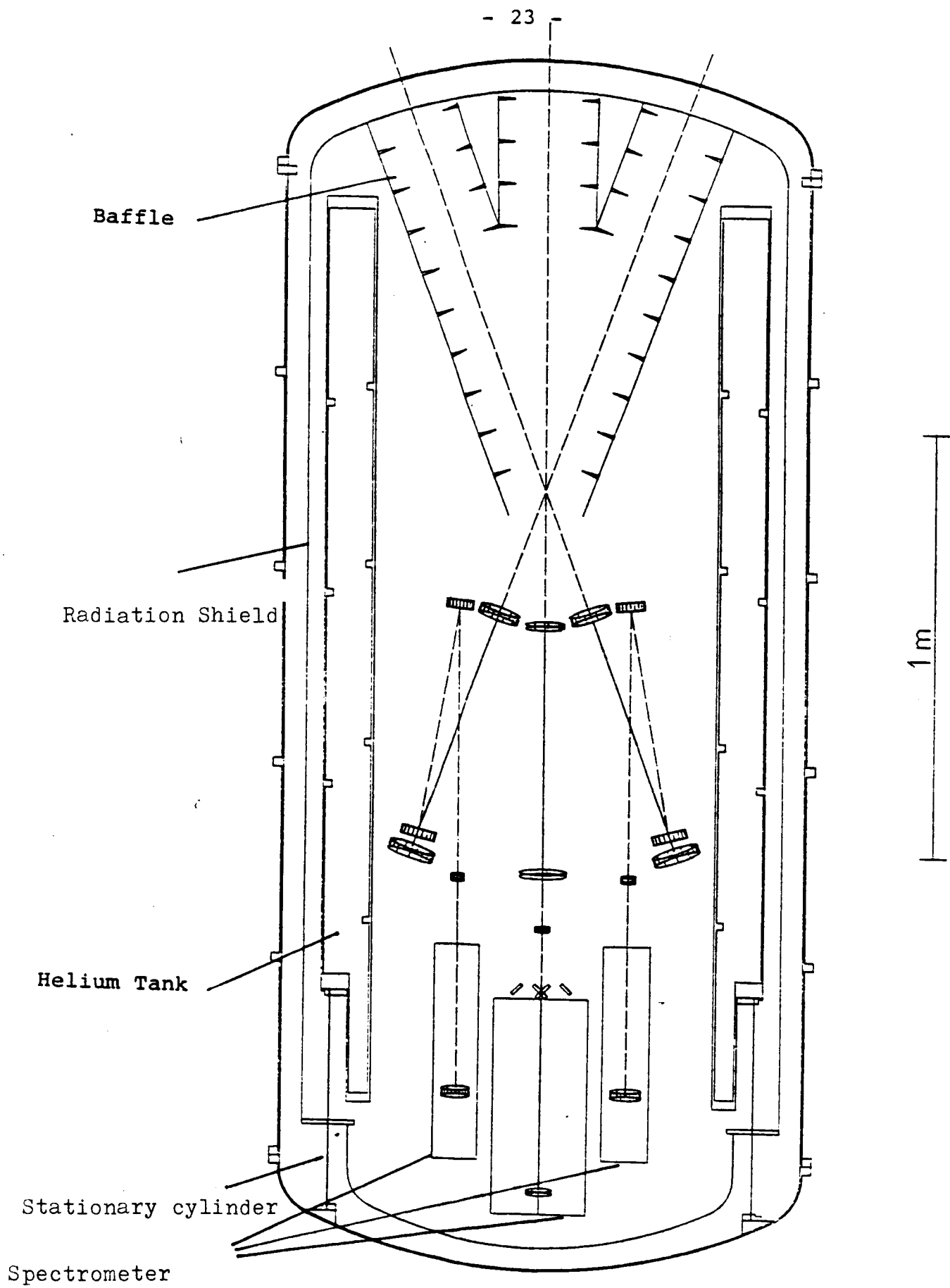


Figure 3.1

It was planned to carry out the CRISTA mission in the spring of 1990 before the tragic Challenger disaster.

ICE (previously ISEE 3)

45

The ICE probe, the former NASA's ISEE 3 satellite, was originally stationed at the libration point (equal attraction between sun and earth) at about 1.5 million km from earth to measure solar winds. ISEE (International Solar Earth Exploration) was renamed ICE (International Cometary Explorer) for its new mission which began on 19.22.83 when it orbited the moon at a height of 120 km. It then crossed the comet tail of the Giacobini-Zinner comet on 9.11.85 at 8000 km distance from the comet core which was at that point a 70 million km distance from the earth. It had no comet-specific experiments on board but nevertheless obtained useful information for:

- Electron plasma	Los Alamos, USA
- Magneto-meter	JPL USA
- Plasma waves	TRW system USA
- Radio waves	Paris observatory, France
- Plasma composition	GSFC USA
- Low-energy cosmic radiation	MPE, Garching, Germany
- Energy-rich particles	London University, GB

The MPE experiment was supported by the FRG during the years from 1974 to 1978.

CAESAR

46

The CAESAR (Auroral Experiment using Scatter and Rockets) mission, concluded in 1985, made a diagnosis of the auroral arc with the aid of radar scattering and coordinated rocket experiments.

Scientific management lay with D. K. Wilhelm of the Max-Planck Institute for Aeronomy.

Two mission launches were carried out at Andoya, Norway, in January 1984 and January 1985.

Formation of auroral arcs has always been of great scientific interest. Although we now have an understanding of some aspects, many questions remain open with respect to the complete concept as well as to the detailed mechanism of auroral physics. One of the urgent questions concerns the energy flow from the magnetosphere to the ionosphere and vice versa. A combination of arc related measurements with scatter equipment and rocket technology should expand our knowledge in all these fields.

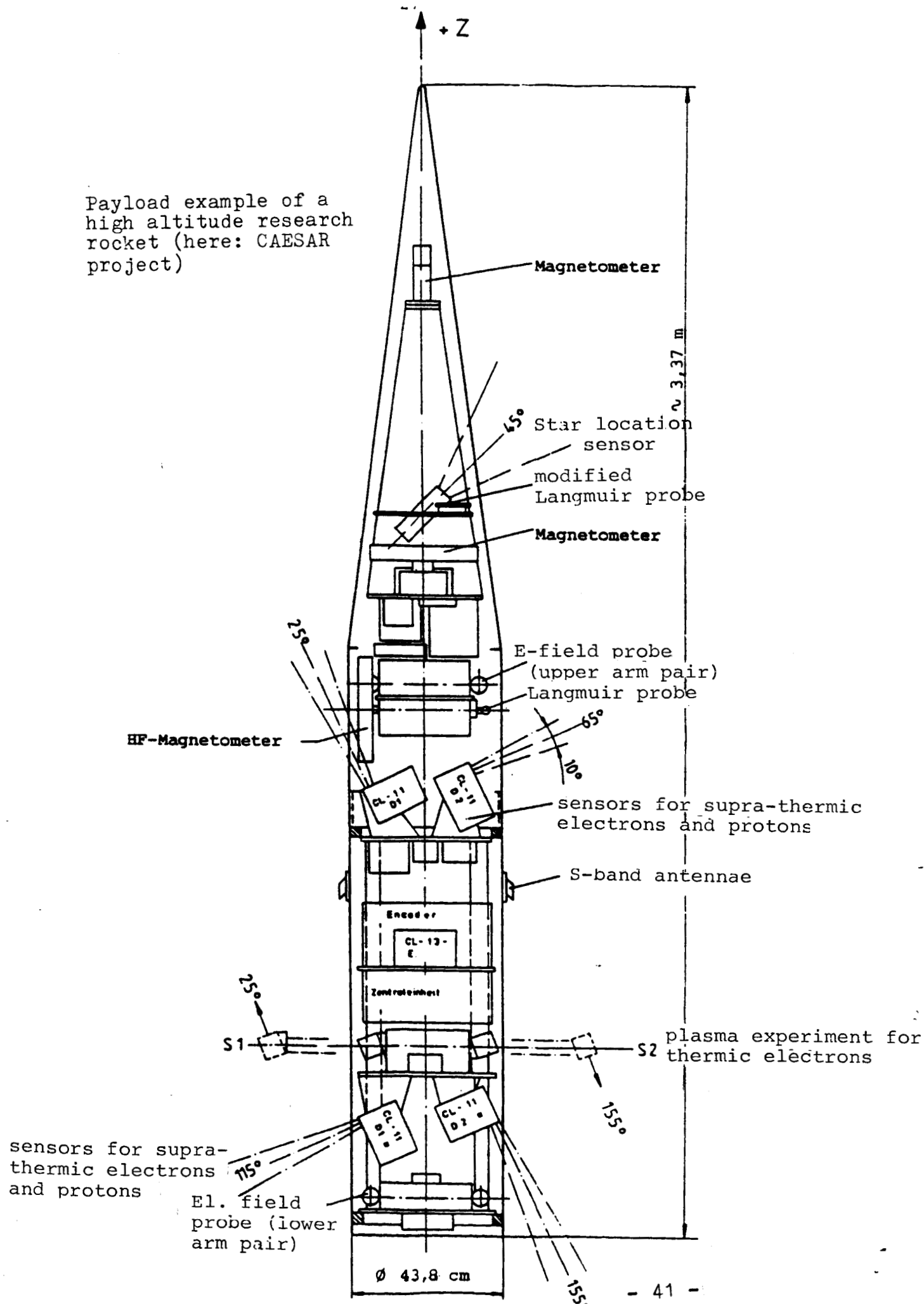
The primary goal of this campaign was the study of field and particle distribution inside and nearby an auroral arc in order to learn the processes which lead to an arc formation and the pertaining energy transport from the magnetosphere to the ionosphere. The modification of the ionosphere, on the other hand, influences the magnetosphere since both systems are closely tied together. In order to deepen our understanding it was necessary to determine the electrical field configuration in the ionosphere and magnetosphere in the close vicinity and above an auroral arc as well as the relationship of field-line parallel flows and their continuation into the ionosphere.

Another aspect was the study of an active, pulsating aura during the recovery phase after a magnetic particle storm. Little is known about such a phenomena and will require some pioneering research. In contrast to the situation of auroral arcs, which involves local processes, it seems to be generally valid that the origin of pulsation formation must be looked for near the geomagnetic equator.

47

Two identical rocket payloads were launched from Andoya, Norway, atop a three-stage Skylark-12 rocket to a height of about 750 km. With the help of EISCAT (European Incoherent Scatter) - which was coordinated in time and space - observations were carried out to

Payload example of a
high altitude research
rocket (here: CAESAR
project)



gain complete information on plasma parameters in the vicinity of an auroral arc.

AMPTE

49

The AMPTE project (Active Magnetospheric Particle Tracer Explorers) is a mutual space research project between the USA, England and the FRG. It consists of three satellites all launched on one Delta rocket at Cape Canaveral on August 16, 1984.

The IRM (Ion Release Module) made in Germany by the Max Planck Institute for Extraterrestrial Physics (MPE) in Garching) released ions inside and outside the earth's magnetosphere into the surrounding plasma. The plasma-physical effects were then analyzed with diagnostic instruments.

A second satellite, CCE (Charge Composition Explorer), produced by the Applied Physics Laboratory (APL, Maryland, USA) was used to measure the natural ion composition of the magnetosphere as well as to show the transport of the artificially space-injected ions towards areas close to earth.

The third satellite, UKS (United Kingdom Satellite) was produced at the Rutherford Appleton Laboratory (England) as a subsidiary satellite of the IRM and which it supports for plasma-diagnostic measurements at a distance of some 100 km from the IRM.

The major aims of the AMPTE mission can be summarized as follows:-

- a) In situ observations of the plasma-physical effects which occur during interaction of two plasmas.
- b) The study of ions entering into the earth's magnetosphere which previously were injected into the solar wind.
- c) The study of ion transport inside the earth's magnetosphere.
- d) Creation of an artificial comet in the 'magnetosheath'.
- e) Study of natural boundaries and boundary layers such as the magneto-pause, bow-shock and the 'neutral sheet'.

The overall scientific management of the project lies with S.M. Krimigis/APL and G. Haerendel/MPE. MPE was responsible for the satellite construction and the execution of the experimental program. MPG was in charge of the design of the diagnostic experiments. Mission control is being carried out by DFVLR/GSOC. The AMPTE project is supported in Germany by the BMFT, in the USA by NASA and in England by SERC. Supervision for the German part is also in the hands of DFVLR-RF.

Two invisible lithium injections were created by the "bow shock" on the 9th, 11th and 20th September 1984.

The first "artificial" comet, i.e. a barium plasma cloud in the solar wind was created by the AMPTE/IRM satellite on 12.27.1984. A second artificial comet was created on 7.18.1985. The local and global diagnostic, compared to the first comet, was considerably improved.

An internal lateral movement of the cloud due to "recoil effect" of accelerated ions, the formation of a large tail and lastly the penetration of the magnetic field without formation of anomalous resistance could be clearly established.

Four evaporation experiments in the tail of the magnetosphere were carried out in the period from March to April 1985. The diagnostic measurements of the IRM satellite will be continued in 1986. Some of IRM's sensors, together with sensors of other space probes (e.g. ISEE and 3/ICE), make it possible to carry out detailed studies of ion and element compositions, directional distribution and the time variations of energetic ions and electrons in the energy range ≥ 5 KeV.

The Solar and Heliospheric Observatory is part of the solar-terrestrial physics program. It is a cornerstone in ESA's long-term planning and, as the name implies, is to observe the sun and its neighborhood.

The project's study phase was completed at the end of 1985 and its launch is planned for 1993 atop an ARIANE 4.

It is hoped that the mission will supply some answers to the following questions:

- Why does the corona exist?
- Where and how is the solar wind accelerated?
- How is the sun's inside structured?

A set of 11 experiments has been assembled to study these questions. They are to investigate the static quantities, the dynamic properties of chromosphere and corona, the study of solar winds at the probe's location and lastly they are to measure the sun's luminous power and to record vibrations occurring at the sun's surface. It is hoped that such types of studies will provide - with the aid of helio-seismology - clues to the sun's inner structure.

In order to meet the experimental criteria the satellite must keep the sun in view continuously and must stay most of the time under the influence of solar winds. Such criteria could not be met with an earth orbit. It is, therefore, planned to let SOHO orbit the L1 liberation point of the earth-sun system, i.e. the point where gravitational forces of sun and earth are cancelled.

This point lies on the connecting line between earth and sun at about 1.5 million km distance from earth. In order to get the satellite to its destination it will first be brought into an earth orbit and will then proceed under its own power.

52

SOHO will have a mass of about 2.2 tons and its energy requirements will be covered mainly by solar cells. The mission length is to be at least two years although it is hoped to expand it to six years.

It has not yet been established which German institutes will participate in this project. ESA will make a flight announcement at which time German institutes can apply in competition with other European facilities.

CLUSTER

53

Together with the SOHO mission CLUSTER is another focal point of the long-term ESA program of researching the sun-earth system.

While SOHO is designed to explore the sun and undisturbed solar winds, CLUSTER is to study the area near earth where the solar winds interact with the earth magnetosphere. The following problems are to be investigated:

- the physics of the boundary layer between two cosmic plasmae and investigation of processes which make it possible to have an exchange of mass, impulse and energy through the boundary layer.
- plasma acceleration processes for field reconfiguration.
- turbulences and diffusion processes.
- shock investigation and associated particle acceleration and wave formation.
- the micro-structure of solar winds.

The structures to be investigated undergo changes with time. In order to distinguish between space and time variations CLUSTER is made up of four individual satellites which will carry out identical plasma studies from neighboring locations.

The orbit has been designed in such a way that all interesting areas can be visited. This will be achieved by an excentric polar orbit whose remotest earth point lies in the equatorial plane. Distances between the satellites will be between 200 km and 3000 km depending on the flight phase.

CLUSTER went through development phase A at the end of 1985 and launch is planned for 1993 together with SOHO. It has not yet been established which German institutes will participate.

54

Comet probe GIOTTO

Comets are large "dirty" snowballs of some kilometers in diameter and mainly made up of frozen water and carbon compounds mixed with dust. Our present knowledge of comets is based on earth-bound observations of comet paths, path disturbances, measurements of comet dust and photolysis fragments.

An international armada of six space probes has for the first time investigated comets at close range. The target was the comet Halley named after the British astronomer Edmund Halley who was the first to describe its path.

Comet Halley has a period of about 76 years. It was observed at the end of May 1911 on its way around the sun. It reached its aphel in 1948 outside the Neptun orbit and was rediscovered in October 1982 more than 1.6 billion kilometers away on its return journey. The subsequent perihel was crossed on February 9, 1986. This is the 29th perihel since the first recording was made in 240 BC by Chinese astronomers.

Five space probes took part in the international race. All reached their goal in March 1986:

VEGA-1 and VEGA-2 of the USSR, launched in December 1984, passed the comet's core at a predetermined distance of 10,000 and 3,000 km. The Japanese MS-T5 and PLANET-A, launched in January and August 1985, passed at a 10 million and 100,000 km distance. ESA's complex space probe GIOTTO, launched in July 1985, came close to a 1,000 km, a distance not without danger. These in-situ measurements are supplemented by the largest ever astronomical observation campaign, coordinated by the IHW (International Halley Watch) and supported by a specially formed group, the IACG (Inter-Agency Consultative Group).

56

The Russian Academy of Sciences made available data previously collected by the VEGA probes providing exact comet core positions to ESA. This so-called "pathfinder concept" permitted a very accurate maneuvering of the GIOTTO probe to within 600 km of comet Halley.

The ESA comet probe has been named GIOTTO in honor of the Florentine painter Giotto di Bondone who in 1301 showed the comet in his painting "The Adoration of the Three Wise Men".

On March 13, 1986 - that is four to five weeks after the comet's perihel - GIOTTO has ten scientific experiments on board which ESA has very carefully selected from a large number of experiment proposals. German experimenters participate extensively in each experiment.

For four experiments German scientists carry the main responsibility as the so-called Principle Investigators. Other German physicists are involved as co-investigators in the six other experiments. This proportional German participation in the Giotto's scientific payload - a yardstick for the high scientific-technical level of extra-terrestrial research in the FRG - carries, of course, a price-tag. 57

The necessary financial means for these projects (including the scientific data evaluation) amounted to more than 43,000,000 DM between 1981 and 1987. The design and construction of the probe and the launching and operation will be financed by ESA's program in which the FRG participates with about 25%. The BMFT made these means available within the framework of basic extraterrestrial research. The project is under the auspices of the German Research Institute for Air and Space Travel (DFVLR) in Cologne-Porz.

The scientific goals of the ten experiments are as follows:

It is to be studied whether comets form a pre-solar fog in the core which is then carried to the edge of the solar system and which later through star disturbances are redirected to the inner core.

It is hoped to find some answers to the conditions of the planetary system at the time it was created by studying the exact composition of comet ice and the nature of dust particle size distribution which contributes considerably to replenish interplanetary dust.

In contrast to planets and moons the creation of comets was of a far less violent nature so that the solar system's original material may have undergone little change and subsequent erosion and fractionating can be dismissed as insignificant.

58

- HMC - Multi-color camera with four different color filters to take up to 3,600 photos of the comet's core which permit the details of objects of about 30 m to be seen. (Principal Investigator is Dr. H.U. Keller of the Max-Planck Institute for Aeronomie in Katlenburg-Lindau, Harz).
- PIA - Dust impact mass spectrometer to record impacting dust particles (Principal Investigator is Dr. J. Kissel of the Max Planck Institute for Nuclear Physics in Heidelberg).
- NMS - Mass spectrometer to study neutral gases and ions (Principal Investigator is Dr. D. Krankowsky of the Max-Planck-Institute for Nuclear Physics in Heidelberg).
- MAG - Magnetometer to study magnetic fields with a two-axial magnetometer (Principal Investigator is Dr. F.M. Neubauer of Cologne University).
- IMS - Ion mass spectrometer to determine the chemical composition of ions evaporated from Halley's comet (Co-Investigator is Dr. R. Schwenn).
- EPA - Detector for energy-rich particles (Co-Investigator is Dr. E. Kirsch).
- JPA - Plasma analysator 1 (Co-Investigator is Dr. B. Wilken).
- RPA - Plasma analysator 2 (Co-Investigator is Dr. A. Korth).

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- DID - Dust impact detector system (Co-Investigators are Dr. E. Gruen and Prof. Dr. E. Igenbergs).
- OPE - Optical probe (Co-Investigator is Prof. Dr. R. Giese).

Ulysses, ISPM, OOE

All present generation space probes have orbits within the ecliptic or, at the most, a few degrees inclined towards it due to energy reasons. They can, therefore, only give a "two-dimensional picture" of the composition and properties of interplanetary space.

The "out of ecliptic" mission begun together by NASA and ESA at the end of 1977 included plans for two space probes to leave the ecliptic and to carry out in situ measurements high over the solar poles for property studies of solar vicinities. It was hoped they would produce detailed information about particles, radiation and fields at high heliographic latitudes almost simultaneously over both poles.

Such orbits can be obtained through a swing-by of Jupiter, i.e., the probes are sent to Jupiter so that its gravity field deforms the orbits in such a way as to fling them out of the ecliptic.

Financial problems led to a budget cut of the NASA probe in 1981 leaving the ISPM (International Solar Polar Mission) only one probe under the direction of ESA. This probe has ten experiments on board, six of which include a German participation with three German Principal Investigators (PI) responsible for three experiments.

- The Cosmic Dust Experiment of the Max-Planck-Institute for Nuclear Physics (MPK), Heidelberg (PI: E. Gruen) measures three dimensional dust distribution and its dynamic behavior for dust masses between 10^{-16} and 10^{-7} g. An entry grid system each with an electron and ion collector permits the measurement of mass, velocity, impact direction and electrical charge of the individual dust particles.

- The LOW-ENERGY-ION Experiment of the MPK, Heidelberg (PI: E. Keppler), consists of four independent special telescopes. These telescopes measure the composition of the low-energy solar and galactic radiation in the energy range from 50 KeV/n to 1 MeV/n as well as their dynamic behavior.
- The INTERSTELLAR GAS Experiment of the MP Ae, Lindau (PI: Rosenbauer) measures the distribution and flow direction of inter-stellar helium.
- M. Sommer of the Max Planck Institute for Extraterrestrial Physics (MPE), Garching, and K.C. Hurley (Toulouse, F) share the management of the EXRAY experiment which measures x-ray radiation and gamma bursts and if possible also to identify their sources with known heavenly bodies.
- B. Wilken (MP Ae, Lindau), is Co-Investigator (CoI) for the SOLAR WIND ION COMPOSITION Experiment (SWICS). This experiment measures the composition with respect to elements and charges and the velocities of major ions of the solar wind.
- H. Kunow (University Kiel) is the CoI for the COSMIC RAY AND CHARGED PARTICLE Experiment of Chicago University. 6 different sensors measure electrons, protons and ions in a wide energy range. The resolution permits a separation of heavy elements of cosmic radiation and the dynamic range covers the lower flows during solar-inactive times as well as the highest eruptions in the Jupiter area.

62

Apart from the probe's active experiments there will also be a passive experiment. A working group headed by the German P.I. Volland, Bonn University, is to study the characteristic modifications of the telemetry signal along the probe's sight-line with respect to charges and fields.

Due to the Challenger disaster the planned launch for May 1986 has been postponed. It is sincerely hoped that the next star window (June 1987) can be used to dispatch the probe. Apart from delays caused by the shuttle's safety problems the question

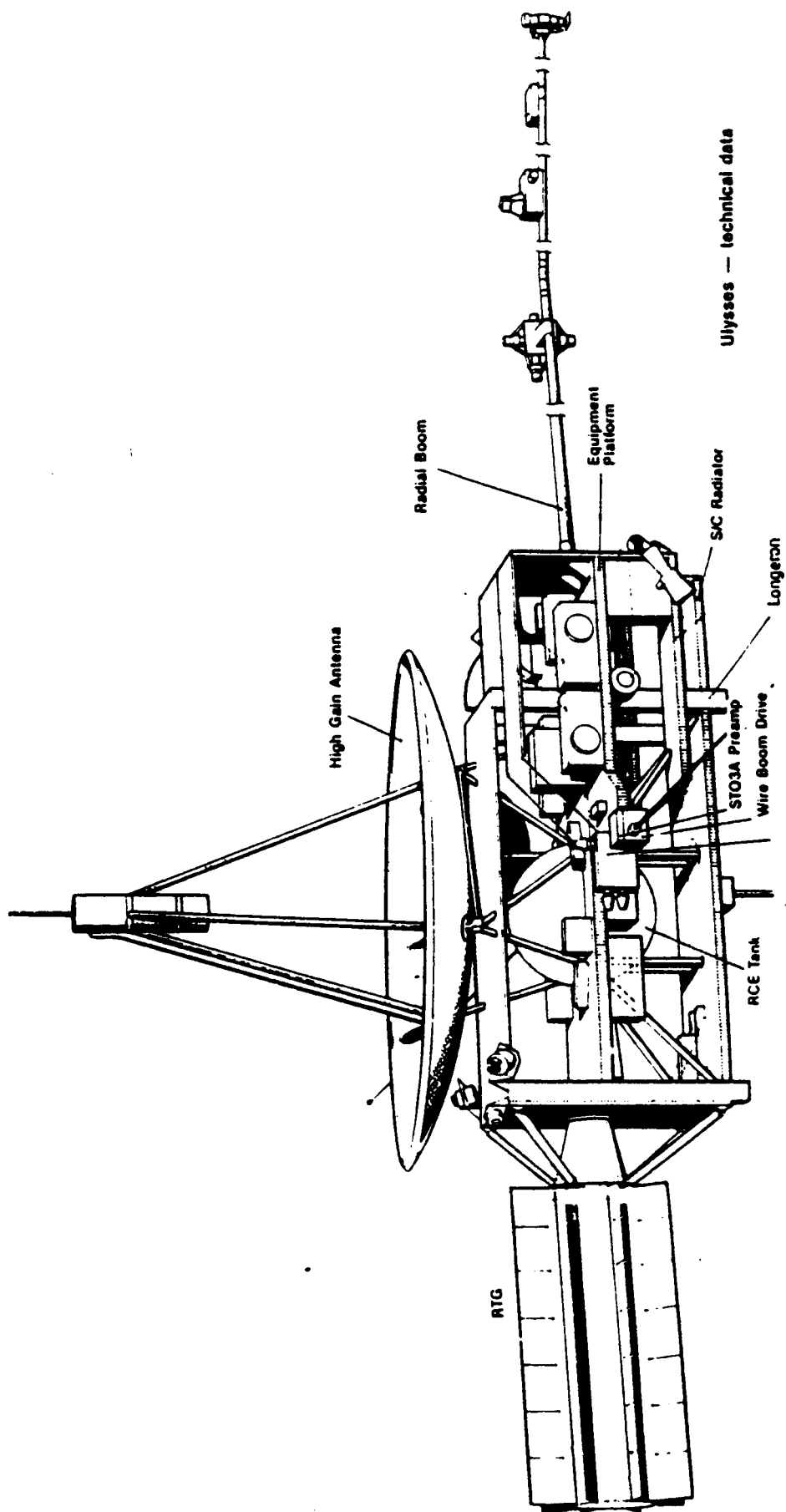


Figure 4.1

arises as to whether the plutonium thermo-electric nuclear generator - necessary for the probe's electric energy supply - will receive a launch permit in Florida.

In the meantime the probe has been renamed once again. Its current name is "Ulysses" based on Dante's hero in the Heavenly Comedy where Ulysses sets off to explore the empty world beyond the sun.

GALILEO

64

The GALILEO mission is part of NASA's program to explore the planetary system in order to gain insights in the origin and development of the solar system and the creation of life on the planets.

The Jupiter mission is to investigate, by means of an orbiter circling the largest planet of the solar system, the targeted planet and its (Galilean) moons, by sending a probe into their atmosphere to study its composition and profile.

The mission's major goals are to study

- the chemical composition and physical condition of Jupiter's atmosphere
- the chemical composition and physical condition of the Galilean moons
- the structure and physical dynamics of Jupiter's magnetosphere.

The Federal Republic of Germany (FRG) has a Memorandum of Understanding between the BMFT and NASA and participates in the GALILEO project as follows:

- two experiments (German PIs) aboard orbiter and probe
- participation as Co-Investigators (Co-I) in four experiments under the direction of a US PI
- attaching one German scientist for the imaging project

- supplying one drive system (Retro Propulsion System) for the position control of the space vehicle, for orbit correction maneuvers and for guiding the vehicle on a path around Jupiter (Jupiter Orbit Insertion)
- assisting in mission operation during the transfer phase to Jupiter and support during the orbit phase.

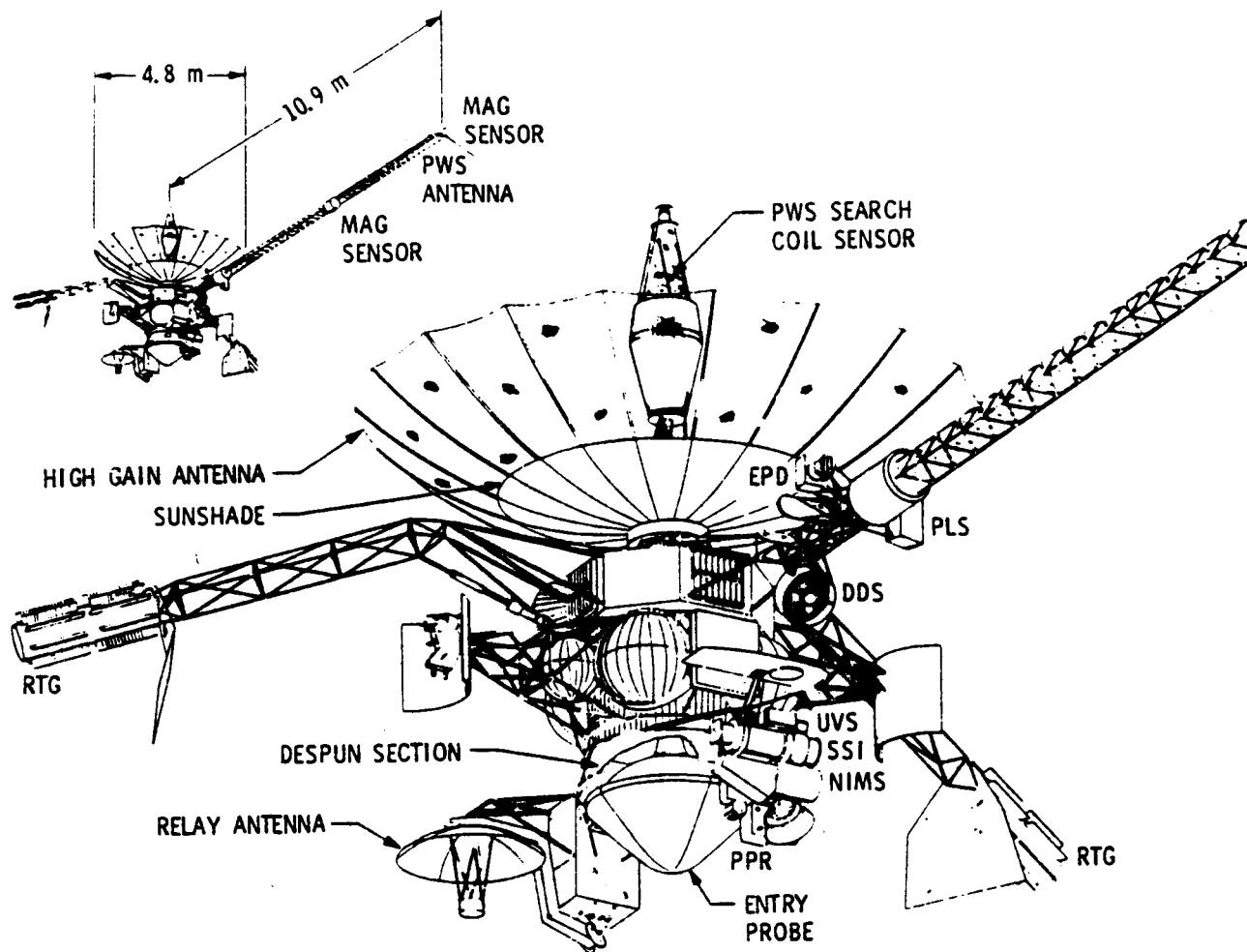
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Details of the all-German and participation projects are as follows:

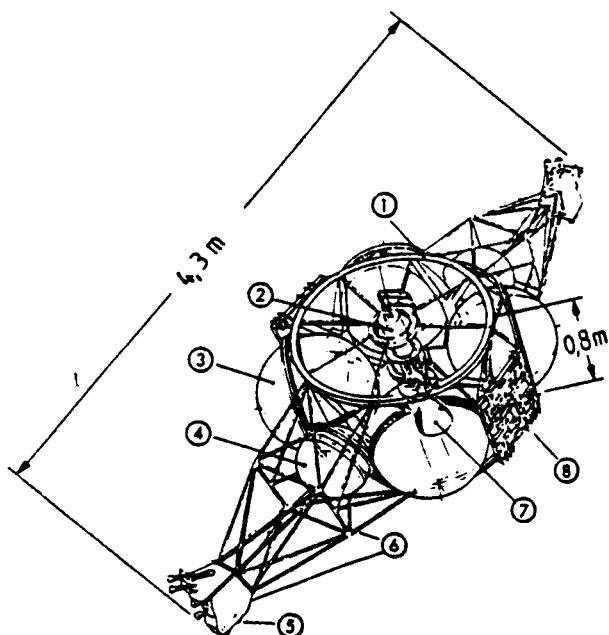
- | | |
|--|-----------|
| - Helium Interferometer/Helium Abundance
PI: U.von Zah, Bonn University | - Probe |
| - Lightning and Radio Emission
CoI: K. Rinnert, MP Ae Lindau | - Probe |
| - Energetic Particle Experiment
CoI: H. Fischer, Kiel University | - Probe |
| - Dust Detector
PI: E. Gruen, MPIK Heidelberg | - Orbiter |
| - Imaging
Team Member G. Neukum, DFVLR Oberpfaffenhofen | - Orbiter |
| - Magnetospheric energetic particle instrument
CoI: B. Wilken, MP Ae Lindau | - Orbiter |
| - Plasma Investigation
CoI: V.M. Vasyliunas, MP Ae Lindau | - Orbiter |

The Retro Propulsion Module (RPM) is a gas pressure system with two types of fuel. The medium-energy fuel combination is monomethylhydrazine (NMH) and di-nitrogen tetroxide (N_2O_4) with an increased nitrogen monoxide portion. The pressurized gas supply system and the fuel shut-off system supply twelve 10 N propulsion modules for position and small orbit correction maneuvers as well as the 400 N module for large orbital corrections from four spherical tanks arranged in a symmetrical fashion. The fuel mass is about 950 kg which provides an acceleration ΔV , of a total of 1,150 m/sec.

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GALILEO SPACECRAFT



- (1) structural
- (2) spin bearing
- (3) (4) fuel tanks
- (4) (2) pressurized gas
- (5) 10 N propulsion modules
(2) in cluster
- (6) thermal control (thermal
mats, electric heating,
boom and cluster)
- (7) 400 N propulsion module
- (8) pressurized gas supply
system
- (9) RPM configuration and
elements

The space shuttle will be used for the launching which includes the high-energy Centaur stage for injection into the interplanetary orbit. The original launch date was May 20, 1986. Following the Challenger loss it is now planned to replace the direct transfer - with a repeating star window every 13 months - with an indirect orbit which includes a second earth swing-by in order to achieve Δ VEGA (Velocity Earth Gravity Assist). Launch is planned for the beginning of December 1987 and arrival at the target planet Jupiter is to be July 1992.

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In September 1992 NASA plans to shuttle-launch the space vehicle CRAF (Comet Rendezvous and Asteroid Flyby Mission). An additional Centaur G stage is to send the Mariner Mark II probe into the orbit of the short-period comet Tempel 2.

It is the intention of BMFT to participate in this mission - as with the GALILEO project - with scientific experiments and by supplying a propulsion system developed in Germany.

Apart from position control the function of the propulsion system is to bring about a close proximity between vehicle and comet and to maintain it for several years. The Rendezvous between CRAF and Tempel 2 will take place in November 1996 and can be maintained up to the next solar point (comet tail formation) due to the satellite's favorable orbital tilt.

Prior to the comet rendezvous the probe will pass the asteroids Malantra (1993) and Hestia (1995) at distances of about 1000 km. Comets and asteroids are the earliest bodies in our solar system. They may contain information with respect to chemical and physical processes which played a role during the formation of our solar system.

The main object of the CRAF mission is the study of atomic, molecular and mineralogical composition of the Tempel 2 comet, its changes during their common flight time as well as observing the formation and development of the comet tail (gas, dust, plasma, dynamics and interaction with the solar wind) when it is close to the perihel (closest solar point).

While passing the asteroids the satellite will investigate their physical and geological properties. 69

The space vehicle will be supplied with: mass spectrometers (for ions and neutral particles), magnetometers, plasma wave analysator, plasma probes (for ions and electrons), dust counters, a dust particle analysator, a spectrometer for various wave lengths and a camera. Most instruments are accommodated at the satellite's outriggers. A penetrator will be anchored to the comet and carry out in situ measurements at the comet's core.

The numerous path maneuvers will require more than 4000 kg of fuel for the probe's main propulsion unit; 16 small propulsion modules are responsible for minor corrections and tri-axial stabilization.

The CRAF project is scheduled to begin late fall of 1987.

CRAF

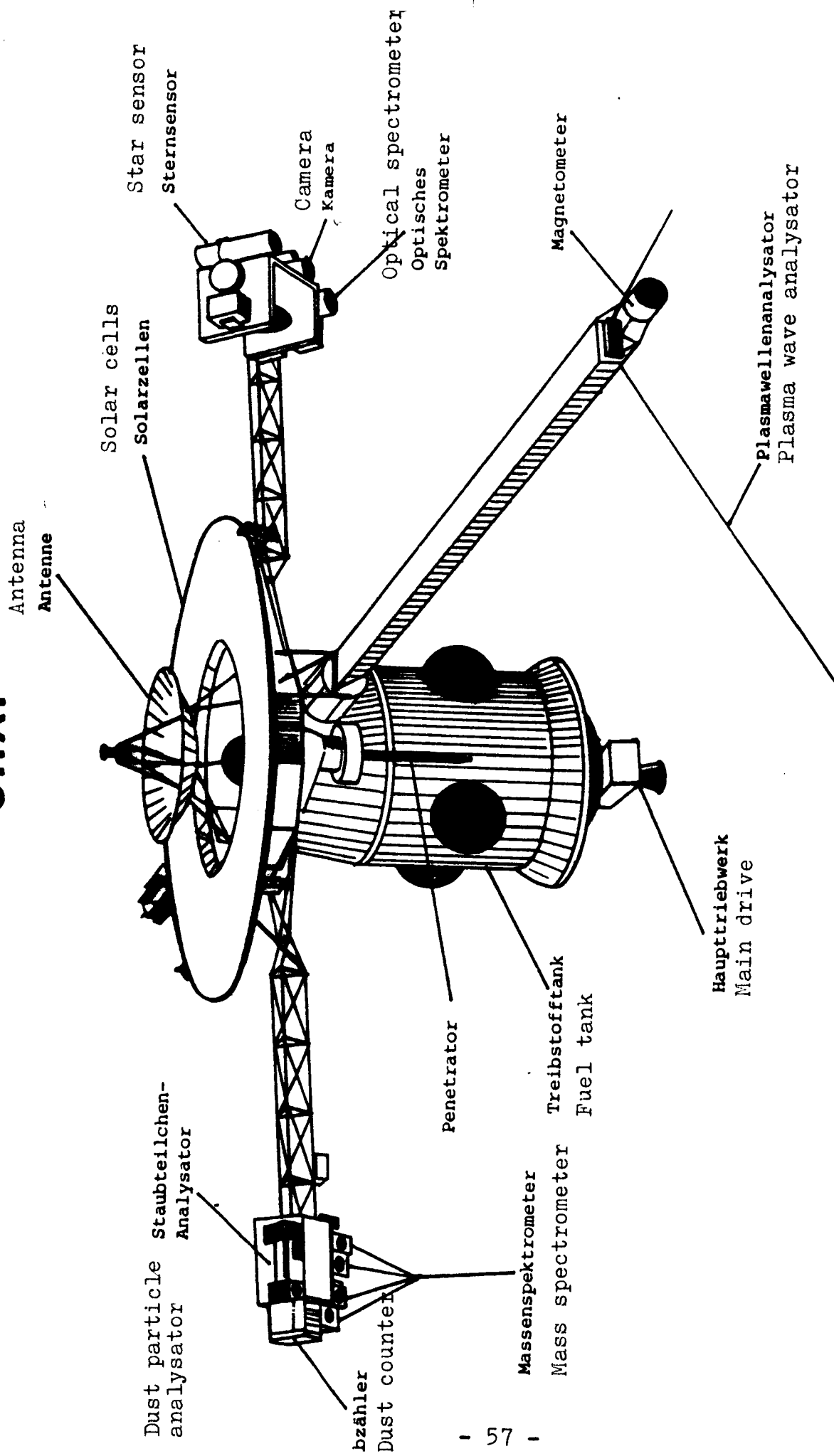


Figure 4.3